CHAPTER 3

ENGINE FUEL AND FUEL METERING SYSTEMS

FUEL SYSTEM REQUIREMENTS

Improvements in aircraft and engines have increased the demands on the fuel system, making it more complicated and increasing the installation, adjustment, and maintenance problems. The fuel system must supply fuel to the carburetor or other metering device under all conditions of ground and air operation. It must function properly at constantly changing altitudes and in any climate. The system should be free of tendency to vapor lock, which can result from changes in ground and in-flight climatic conditions.

On small aircraft a simple gravity-feed fuel system consisting of a tank to supply fuel to the engine is often installed. On multi-engine aircraft, complex systems are necessary so that fuel can be pumped from any combination of tanks to any combination of engines. Provisions for transferring fuel from one tank to another may also be included on large aircraft.

Vapor Lock

Normally the fuel remains in a liquid state until it is discharged into the air stream and then instantly changes to a vapor. Under certain conditions, however, the fuel may vaporize in the lines, pumps, or other units. The vapor pockets formed by this premature vaporization restrict the fuel flow through units which are designed to handle liquids rather than gases. The resulting partial or complete interruption of the fuel flow is called vapor lock. The three general causes of vapor lock are the lowering of the pressure on the fuel, high fuel temperatures, and excessive fuel turbulence.

At high altitudes, the pressure on the fuel in the tank is low. This lowers the boiling point of the fuel and causes vapor bubbles to form. This vapor trapped in the fuel may cause vapor lock in the fuel system.

Transfer of heat from the engine tends to cause boiling of the fuel in the lines and the pump. This tendency is increased if the fuel in the tank is warm. High fuel temperatures often combine with low pressure to increase vapor formation. This is most apt to occur during a rapid climb on a hot day. As the aircraft climbs, the outside temperature drops, but the fuel does not lose temperature rapidly. If the fuel is warm enough at takeoff, it retains enough heat to boil easily at high altitude.

The chief causes of fuel turbulence are sloshing of the fuel in the tanks, the mechanical action of the engine-driven pump, and sharp bends or rises in the fuel lines. Sloshing in the tank tends to mix air with the fuel. As this mixture passes through the lines, the trapped air separates from the fuel and forms vapor pockets at any point where there are abrupt changes in direction or steep rises. Turbulence in the fuel pump often combines with the low pressure at the pump inlet to form a vapor lock at this point.

Vapor lock can become serious enough to block the fuel flow completely and stop the engine. Even small amounts of vapor in the inlet line restrict the flow to the engine-driven pump and reduce its output pressure.

To reduce the possibility of vapor lock, fuel lines are kept away from sources of heat; also, sharp bends and steep rises are avoided. In addition, the volatility of the fuel is controlled in manufacture so that it does not vaporize too readily. The major improvement in reducing vapor lock, however, is the incorporation of booster pumps in the fuel system. These pumps keep the fuel in the lines to the engine-driven pump under pressure. The slight pressure on the fuel reduces vapor formation and aids in moving a vapor pocket along. The booster pump also releases vapor from the fuel as it passes through the pump. The vapor moves upward through the fuel in the tank and out the tank vents.

To prevent the small amount of vapor which remains in the fuel from upsetting its metering action, vapor eliminators are installed in some fuel systems ahead of the metering device or are built into this unit.

BASIC FUEL SYSTEM

The basic parts of a fuel system include tanks, booster pumps, lines, selector valves, strainers, engine-driven pumps, and pressure gages. A review of Chapter 4 in the General Handbook will provide some information concerning these components. Additional information is presented later in this chapter.

Generally, there are several tanks, even in a simple system, to store the required amount of fuel. The location of these tanks depends on both the fuel system design and the structural design of the aircraft. From each tank, a line leads to the selector valve. This valve is set from the cockpit to select the tank from which fuel is to be delivered to the engine. The booster pump forces fuel through the selector valve to the main line strainer. This filtering unit, located in the lowest part of the system, removes water and dirt from the fuel. During starting, the booster pump forces fuel through a bypass in the engine-driven pump to the metering device. Once the engine-driven pump is rotating at sufficient speed, it takes over and delivers fuel to the metering device at the specified pressure.

The airframe fuel system begins with the fuel tank and ends at the engine fuel system. The engine fuel system usually includes the engine-driven pumps and the fuel metering systems. In aircraft powered with a reciprocating engine, the fuel metering system consists of the air- and fuel-control devices from the point where the fuel enters the first control unit until the fuel is injected into the supercharger section, intake pipe, or cylinder. For example, the fuel metering system of the Continental IO-470L engine consists of the fuel/air control unit, the injector pump, the fuel manifold valve, and the fuel discharge nozzles. On the Pratt and Whitney R-1830-94 engine, the fuel metering system consists of the carburetor, the fuel feed valve, and the carburetor accelerating pump. In the latter case, the fuel feed valve and the accelerating pump are mounted on the engine and are engine manufacturer's parts. However, they still constitute a part of the basic fuel metering system.

The fuel metering system on current reciprocating engines meters the fuel at a predetermined ratio to airflow. The airflow to the engine is controlled by the carburetor or fuel/air control unit.

The fuel metering system of the gas turbine engine consists of a jet fuel control and may extend to and include the fuel nozzles. On some turboprop engines a temperature datum valve is a part of the engine fuel system. The rate of fuel delivery is a function of air mass flow, compressor inlet temperature, compressor discharge pressure, r.p.m., and combustion chamber pressure.

The fuel metering system must operate satisfactorily to ensure efficient engine operation as measured by power output, operating temperatures, and range of the aircraft. Because of variations in design of different fuel metering systems, the expected performance of any one piece of equipment, as well as the difficulties it can cause, will vary.

FUEL METERING DEVICES FOR RECIPROCATING ENGINES

This section explains the systems which deliver the correct mixture of fuel and air to the engine combustion chambers. In the discussion of each system, the general purpose and operating principles are stressed, with particular emphasis on the basic principles of operation. No attempt is made to give detailed operating and maintenance instructions for specific types and makes of equipment. For the specific information needed to inspect or maintain a particular installation or unit, consult the manufacturer's instructions.

The basic requirement of a fuel metering system

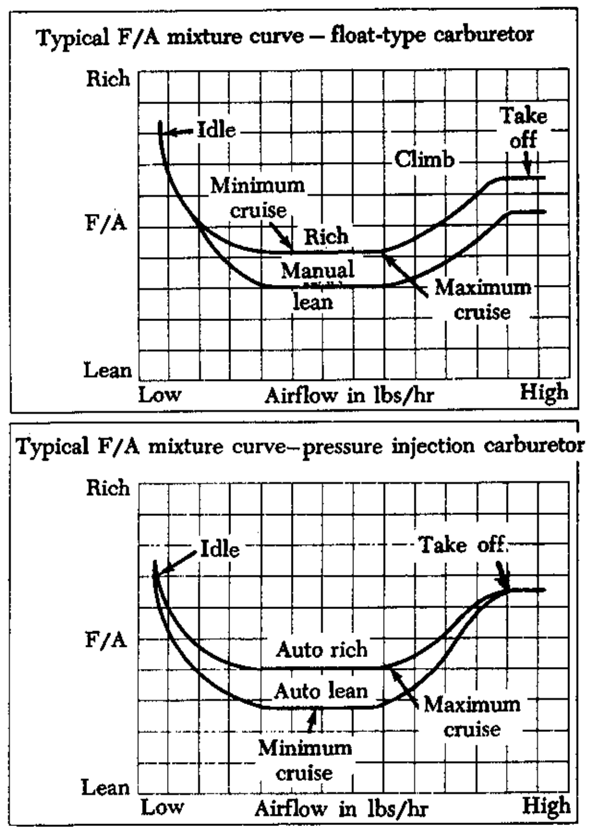


FIGURE 3–1. Fuel/air mixture curves.

is the same, regardless of the type of system used or the model engine on which the equipment is installed. It must meter fuel proportionately to air to establish the proper fuel/air mixture ratio for the engine at all speeds and altitudes at which the engine may be operated. In the fuel/air mixture curves shown in figure 3–1, note that the basic best power and best economy fuel/air mixture requirements for all reciprocating engines are approximately the same.

A second requirement of the fuel metering system is to atomize and distribute the fuel from the carburetor into the mass airflow in such a manner that the air charges going to all cylinders will hold similar amounts of fuel so that the fuel/air mixture reaching each cylinder is of the same ratio.

Carburetors tend to run richer at altitude than at ground level, because of the decreased density of the airflow through the carburetor throat for a given volume of air per hour to the engine. Thus, it is necessary that a mixture control be provided to lean the mixture and compensate for this natural enrichment. Some aircraft use carburetors in which the mixture control is operated manually. Other aircraft employ carburetors which automatically lean the carburetor mixture at altitude to maintain the proper fuel/air mixture.

The rich mixture requirements for an aircraft engine are established by running a power curve to determine the fuel/air mixture for obtaining maximum usable power. This curve (figure 3–2) is plotted at 100-r.p.m. intervals from idle speed to takeoff speed.

Since it is necessary in the power range to add fuel to the basic fuel/air mixture requirements to keep cylinder-head temperatures in a safe range, the fuel mixture must become gradually richer as powers above cruise are used. (See figure 3–1.) In the power range, the engine will run on a much leaner mixture, as indicated in the curves. However, on the leaner mixture, cylinder-head temperature would exceed the maximum permissible temperatures and detonation would occur.

The best economy setting is established by running a series of curves through the cruise range, as shown in the graph in figure 3–3, the low point (auto-lean) in the curve being the fuel/air mixture where the minimum fuel per horsepower is used. In this range the engine will operate normally on slightly leaner mixtures and will obviously operate on richer mixtures than the low-point mixture. If a mixture leaner than that specified for the engine is used, the leanest cylinder of the engine is apt to backfire, because the slower burning rate of the lean mixture results in a continued burning in the cylinder when the next intake stroke starts.

Fuel/Air Mixtures

Gasoline and other liquid fuels will not burn at all unless they are mixed with air. If the mixture is to burn properly within the engine cylinder, the ratio of air to fuel must be kept within a certain range.

It would be more accurate to state that the fuel is burned with the oxygen in the air. Seventy-eight percent of air by volume is nitrogen, which is inert and does not participate in the combustion process, and 21% is oxygen. Heat is generated by burning the mixture of gasoline and oxygen. Nitrogen and gaseous byproducts of combustion absorb this heat energy and turn it into power by expansion. The mixture proportion of fuel and air by weight is of extreme importance to engine performance. The

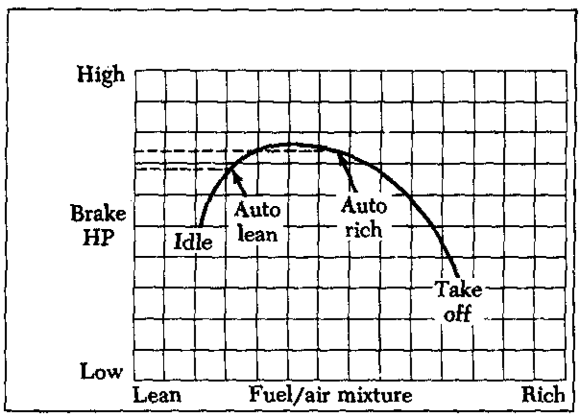


FIGURE 3–2. Power versus fuel/air mixture curve.

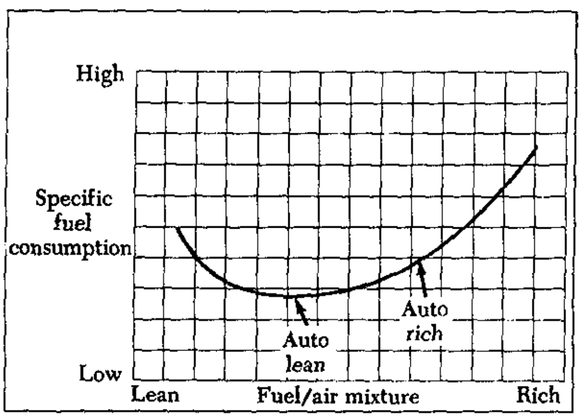


FIGURE 3–3. Specific fuel consumption curve.

characteristics of a given mixture can be measured in terms of flame speed and combustion temperature.

The composition of the fuel/air mixture is described by the mixture ratio. For example, a mixture with a ratio of 12 to 1 (12:1) is made up of 12 lbs. of air and 1 lb. of fuel. The ratio is expressed in weight because the volume of air varies greatly with temperature and pressure. The mixture ratio can also be expressed as a decimal. Thus, a fuel/air ratio of 12:1 and a fuel/air ratio of 0.083 describe the same mixture ratio. Air and gasoline mixtures as rich as 8:1 and as lean as 16:1 will burn in an engine cylinder. The engine develops maximum power with a mixture of approximately 12 parts of air and 1 part of gasoline.

From the chemist's point of view the perfect mixture for combustion of fuel and air would be 0.067 lb. of fuel to 1 lb. of air (mixture ratio of 15:1). The scientist calls this chemically correct combination a stoichiometric mixture (pronounced stoy-key-o-metric). With this mixture (given sufficient time and turbulence), all the fuel and all the oxygen in the air will be completely used in the combustion process. The stoichiometric mixture produces the highest combustion temperatures because the proportion of heat released to a mass of charge (fuel and air) is the greatest. However, the mixture is seldom used because it does not result in either the greatest economy or the greatest power for the airflow or manifold pressure.

If more fuel is added to the same quantity of air charge than the amount giving a chemically perfect mixture, changes of power and temperature will occur. The combustion gas temperature will be lowered as the mixture is enriched, and the power will increase until the fuel/air ratio is approximately 0.0725. From 0.0725 fuel/air ratio to 0.080 fuel/air ratio the power will remain essentially constant even though the combustion temperature continues downward. Mixtures from 0.0725 fuel/air ratio to 0.080 fuel/air ratio are called best power mixtures, since their use results in the greatest power for a given airflow or manifold pressure. In this fuel/air ratio range, there is no increase in the total heat released, but the weight of nitrogen and combustion products is augmented by the vapor formed with the excess fuel; thus, the working mass of the charge is increased. In addition, the extra fuel in the charge (over the stoichiometric mixture) speeds up the combustion process, which provides a favorable time factor in converting fuel energy into power.

Enriching a fuel/air ratio above 0.080 results in the loss of power besides reduction of temperature, as the cooling effects of excess fuel overtake the favorable factor of increased mass. The reduced temperature and slower rate of burning lead to an increasing loss of combustion efficiency.

If, with constant airflow, the mixture is leaned below 0.067 fuel/air ratio, power and temperature will decrease together. This time, the loss of power is not a liability but an asset. The purpose in leaning is to save fuel. Air is free and available in limitless quantities. The object is to obtain the required power with the least fuel flow and to let the air consumption take care of itself.

A measure of the economical use of fuel is called SFC (specific fuel consumption), which is the lbs. of fuel per hr. per hp. Thus, SFC = lbs. fuel/hr./hp. By using this ratio, the engine's use of fuel at various power settings can be compared. When leaning below 0.067 fuel/air ratio with constant airflow, even though the power diminishes, the cost in fuel to support each horsepower hour (SFC) also is lowered for a while. While the mixture charge is becoming weaker, this loss of strength occurs at a rate slower than that of the reduction of fuel flow. This favorable tendency continues until a mixture strength known as best economy is reached. With this fuel/air ratio, the required hp. is developed with the least fuel flow, or, to put it another way, a given fuel flow produces the most power.

The best economy fuel/air ratio varies somewhat with r.p.m. and other conditions, but, for cruise powers on most reciprocating engines, it is sufficiently accurate to define this range of operation as being from 0.060 to 0.065 fuel/air ratios with retard spark, and from 0.055 to 0.061 fuel/air ratios with advance spark. These are the most commonly used fuel/air ratios on aircraft where manual leaning is practiced.

Below the best economical mixture strength, power and temperature continue to fall with constant airflow while the SFC increases. As the fuel/air ratio is reduced further, combustion becomes so cool and slow that power for a given manifold pressure becomes so low as to be uneconomical. The cooling effect of rich or lean mixtures results from the excess fuel or air over that needed for combustion. Internal cylinder cooling is obtained from unused fuel when fuel/air ratios above 0.067 are used. The same function is per-formed by excess air when fuel/air ratios below 0.067 are used.

Varying the mixture strength of the charge produces changes in the engine operating condiition affecting power, temperature, and spark-timing requirements. The best power fuel/air ratio is desirable when the greatest power from a given airflow is required. The best economy mixture results from obtaining the given power output with the least fuel flow. The fuel/air ratio which gives most efficient operation varies with engine speed and power output.

In the graph showing this variation in fuel/air ratio (figure 3–1), note that the mixture is rich at both idling and high-speed operation and is lean through the cruising range. At idling speed, some air or exhaust gas is drawn into the cylinder through the exhaust port during valve overlap. The mixture which enters the cylinder through the intake port must be rich enough to compensate for this gas or additional air. At cruising power, lean mixtures save fuel and increase the range of the airplane. An engine running near full power requires a rich mixture to prevent overheating and detonation. Since the engine is operated at full power for only short periods, the high fuel consumption is not a serious matter. If an engine is operating on too lean a mixture and adjustments are made to increase the amount of fuel, the power output of the engine increases rapidly at first, then gradually until maximum power is reached. With a further increase in the amount of fuel, the power output drops gradually at first, then more rapidly as the mixture is further enriched.

There are specific instructions concerning mixture ratios for each type of engine under various operating conditions. Failure to follow these instructions will result in poor performance and often in damage to the engine. Excessively rich mixtures result in loss of power and waste of fuel. With the engine operating near its maximum output, very lean mixtures will cause a loss of power and under certain conditions, serious overheating. When the engine is operated on a lean mixture, the cylinder head temperature gage should be watched closely. If the mixture is excessively lean, the engine may backfire through the induction system or stop completely. Backfire results from slow burning of the lean mixture. If the charge is still burning when the intake valve opens, it ignites the fresh mixture and the flame travels back through the combustible mixture in the induction system.

CARBURETION PRINCIPLES

Venturi Principles

The carburetor must measure the airflow through the induction system and use this measurement to regulate the amount of fuel discharged into the airstream. The air measuring unit is the venturi, which makes use of a basic law of physics: ***as the velocity of a gas or liquid increases, the pressure decreases.*** As shown in the diagram of the simple venturi (figure 3–4), it is a passageway or tube in which there is a narrow portion called the throat. As the air speeds up to get through the narrow portion, its pressure drops. Note that the pressure in the throat is lower than that in any other part of the venturi. This pressure drop is proportional to the velocity and is, therefore, a measure of the airflow. The basic operating principle of most carburetors depends on the differential pressure between the inlet and the venturi throat.

Application of Venturi Principle to Carburetor

The carburetor is mounted on the engine so that air to the cylinders passes through the barrel, the part of the carburetor which contains the venturi. The size and shape of the venturi depends on the requirements of the engine for which the carburetor is designed. A carburetor for a high-powered engine may have one large venturi or several small ones. The air may flow either up or down the venturi, depending on the design of the engine and the carburetor. Those in which the air passes downward are known as downdraft carburetors, and those in which the air passes upward are called updraft carburetors.

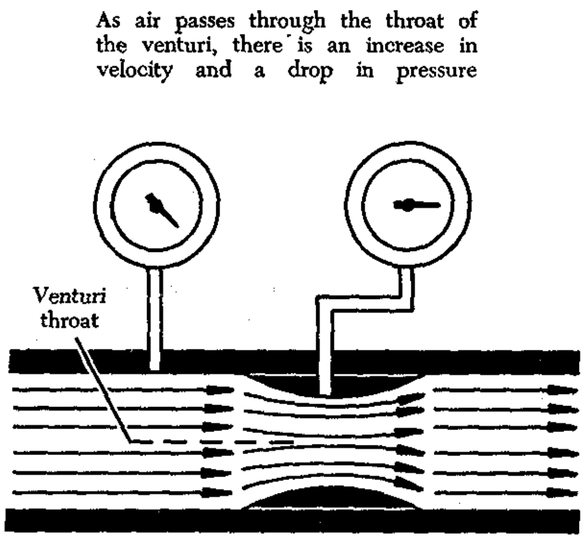


FIGURE 3–4. Simple venturi.

Air can be drawn through a rubber tube by placing one end in the mouth and exerting a sucking action. Actually, the pressure inside the tube is lowered and atmospheric pressure pushes air into the open end. Air flows through the induction system in the same manner. When a piston moves toward the crankshaft on the intake stroke, the pressure in the cylinder is lowered. Air rushes through the carburetor and intake manifold to the cylinder due to the higher pressure at the carburetor intake. Even in a supercharged engine operating at high manifold pressure, there is still a low pressure at the engine side of the carburetor. Atmospheric pressure at the air intake pushes air through the carburetor to the supercharger inlet.

The throttle valve is located between the venturi and the engine. Mechanical linkage connects this valve with the throttle lever in the cockpit. By means of the throttle, airflow to the cylinders is regulated and controls the power output of the engine. It is the throttle valve in your automobile carburetor which opens when you "step on the gas." Actually, more air is admitted to the engine, and the carburetor automatically supplies enough additional gasoline to maintain the correct fuel/air ratio. The throttle valve obstructs the passage of air very little when it is parallel with the flow. This is the wide-open position. Throttle action is illustrated in figure 3–5. Note how it restricts the airflow more and more as it rotates toward the closed position.

Metering and Discharge of Fuel

In the illustration showing the discharge of fuel into the airstream (figure 3–6), locate the inlet through which fuel enters the carburetor from the engine-driven pump. The float-operated needle valve regulates the flow through the inlet and, in this way, maintains the correct level in the fuel chamber. This level must be slightly below the

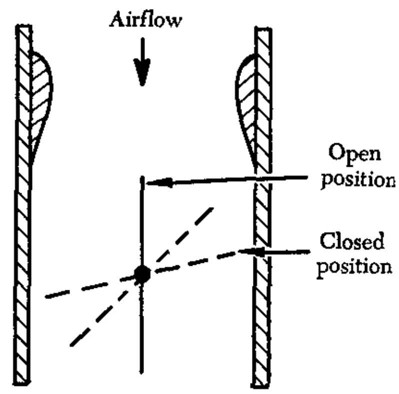


FIGURE 3–5. Throttle action.

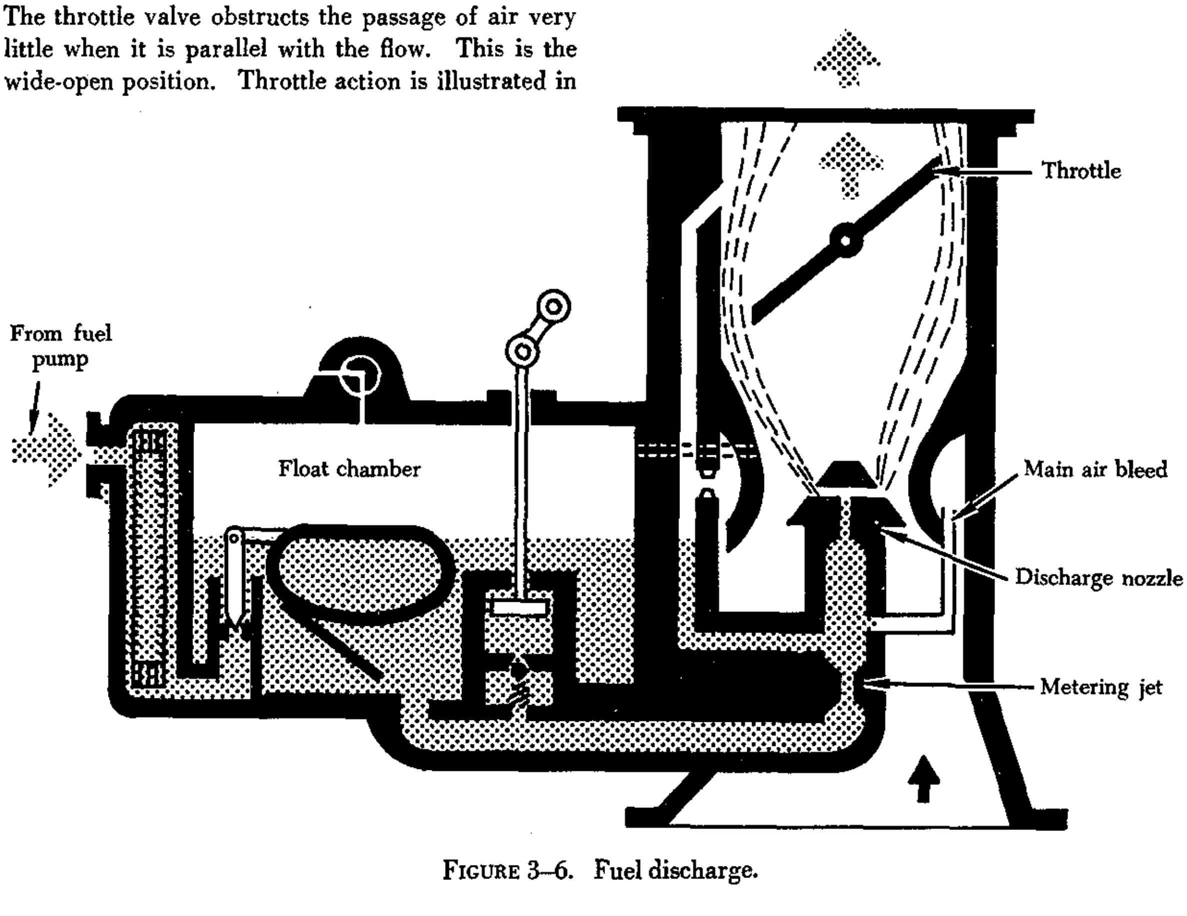


FIGURE 3–6. Fuel discharge.

outlet of the discharge nozzle to prevent overflow when the engine is not running.

The discharge nozzle is located in the throat of the venturi at the point where the lowest drop in pressure occurs as air passes through the carburetor to the engine cylinders. Thus, there are two different pressures acting on the fuel in the carburetor—a low pressure at the discharge nozzle and a higher (atmospheric) pressure in the float chamber. The higher pressure in the float chamber forces the fuel through the discharge nozzle into the airstream. If the throttle is opened wider to increase the airflow to the engine, there is a greater drop in pressure at the venturi throat. Because of the higher differential pressure, the fuel discharge increases in proportion to the increase in airflow. If the throttle is moved toward the "closed" position, the airflow and fuel flow decrease.

The fuel must pass through the metering jet (figure 3–6) to reach the discharge nozzle. The size of this jet determines the rate of fuel discharge at each differential pressure. If the jet is replaced with a larger one, the fuel flow will increase, resulting in a richer mixture. If a smaller jet is installed, there will be a decrease in fuel flow and a leaner mixture.

CARBURETOR SYSTEMS

To provide for engine operation under various loads and at different engine speeds, each carburetor has six systems:

(1) Main metering.
(2) Idling.
(3) Accelerating.
(4) Mixture control.
(5) Idle cutoff.
(6) Power enrichment or economizer.

Each of these systems has a definite function. It may act alone or with one or more of the others.

The main metering system supplies fuel to the engine at all speeds above idling. The fuel discharged by this system is determined by the drop in pressure in the venturi throat.

A separate system is necessary for idling because the main metering system is unreliable at very low engine speeds. At low speeds the throttle is nearly closed. As a result, the velocity of the air through the venturi is low and there is little drop in pressure. Consequently, the differential pressure is not sufficient to operate the main metering system, and no fuel is discharged from this system. Therefore, most carburetors have an idling system to supply fuel to the engine at low engine speeds.

The accelerating system supplies extra fuel during increases in engine power. When the throttle is opened to obtain more power from the engine, the airflow through the carburetor increases. The main metering system then increases the fuel discharge. During sudden acceleration, however, the increase in airflow is so rapid that there is a slight time lag before the increase in fuel discharge is sufficient to provide the correct mixture ratio with the new airflow. By supplying extra fuel during this period, the accelerating system prevents a temporary leaning out of the mixture and gives smooth acceleration.

The mixture control system determines the ratio of fuel to air in the mixture. By means of a cockpit control, the mechanic, pilot, or engineer can select the mixture ratio to suit operating conditions. In addition to these manual controls, many carburetors have automatic mixture controls so that the fuel/air ratio, once it is selected, does not change with variations in air density. This is necessary because, as the airplane climbs and the atmospheric pressure decreases, there is a corresponding decrease in the weight of air passing through the induction system. The volume, however, remains constant, and, since it is the volume of airflow which determines the pressure drop at the throat of the venturi, the carburetor tends to meter the same amount of fuel to this thin air as to the dense air at sea level. Thus, the natural tendency is for the mixture to become richer as the airplane gains altitude. The automatic mixture control prevents this by decreasing the rate of fuel discharge to compensate for the decrease in air density.

The carburetor has an idle cutoff system so that the fuel can be shut off to stop the engine. This system, incorporated in the manual mixture control, stops the fuel discharge from the carburetor completely when the mixture control lever is set to the "idle cutoff" position. In any discussion of the idle cutoff system, this question usually comes up: Why is an aircraft engine stopped by shutting off the fuel rather than by turning off the ignition? To answer this question, it is necessary to examine the results of both methods. If the ignition is turned off with the carburetor still supplying fuel, fresh fuel/air mixture continues to pass through the induction system to the cylinders while the engine is coasting to a stop. If the engine is excessively hot, this combustible mixture may be ignited by local hot spots within the combustion chambers, and the engine may keep on running or kick backward. Again, the mixture may pass out of the cylinders unburned but be ignited in the hot exhaust manifold. More often, however, the engine will come to an apparently normal stop but have a combustible mixture in the induction passages, the cylinders, and the exhaust system. This is an unsafe condition since the engine may kick over after it has been stopped and seriously injure anyone near the propeller. On the other hand, when the engine is shut down by means of the idle cutoff system, the spark plugs continue to ignite the fuel/air mixture until the fuel discharge from the carburetor ceases. This alone should prevent the engine from coming to a stop with a combustible mixture in the cylinders.

Some engine manufacturers suggest that just before the propeller stops turning, the throttle be opened wide so that the pistons can pump fresh air through the induction system, the cylinders, and the exhaust system as an added precaution against accidental kick-over. After the engine has come to a complete stop, the ignition switch is turned to the "off" position.

The power enrichment system automatically increases the richness of the mixture during high-power operation. In this way, it makes possible the variation in fuel/air ratio necessary to fit different operating conditions. Remember that at cruising speeds a lean mixture is desirable for economy reasons, while at high-power output the mixture must be rich to obtain maximum power and to aid in cooling the engine. The power enrichment system automatically brings about the necessary change in the fuel/air ratio. Essentially, it is a valve which is closed at cruising speeds and opens to supply extra fuel to the mixture during high-power operation. Although it increases the fuel flow at high power, the power enrichment system is actually a fuel saving device. Without this system, it would be necessary to operate the engine on a rich mixture over the complete power range. The mixture would then be richer than necessary at cruising speed to ensure safe operation at maximum power. The power enrichment system is sometimes called an "economizer" or a "power compensator."

Although the various systems have been discussed separately, the carburetor functions as a unit. The fact that one system is in operation does not necessarily prevent another from functioning. At the same time that the main metering system is discharging fuel in proportion to the airflow, the mixture control system determines whether the resultant mixture will be rich or lean. If the throttle is suddenly opened wide, the accelerating and power enrichment systems act to add fuel to that already being discharged by the main metering system.

CARBURETOR TYPES

In the discussion of the basic carburetor principles, the fuel was shown stored in a float chamber and discharged from a nozzle located in the venturi throat. With a few added features to make it workable, this becomes the main metering system of the float-type carburetor. This type of carburetor, complete with idling, accelerating, mixture control, idle cutoff, and power enrichment systems, is probably the most common of all carburetor types.

However, the float-type carburetor has several distinct disadvantages. In the first place, imagine the effect that abrupt maneuvers have on the float action. In the second place, the fact that its fuel must be discharged at low pressure leads to incomplete vaporization and difficulty in discharging fuel into some types of supercharged systems. The chief disadvantage of the float carburetor, however, is its icing tendency. Since the float carburetor must discharge fuel at a point of low pressure, the discharge nozzle must be located at the venturi throat, and the throttle valve must be on the engine side of the discharge nozzle. This means that the drop in temperature due to fuel vaporization takes place within the venturi. As a result, ice readily forms in the venturi and on the throttle valve.

A pressure-type carburetor discharges fuel into the airstream at a pressure well above atmospheric. This results in better vaporization and permits the discharge of fuel into the airstream on the engine side of the throttle valve. With the discharge nozzle located at this point, the drop in temperature due to fuel vaporization takes place after the air has passed the throttle valve and at a point where engine heat tends to offset it. Thus, the danger of fuel vaporization icing is practically eliminated. The effects of rapid maneuvers and rough air on the pressure-type carburetors are negligible since its fuel chambers remain filled under all operating conditions.

CARBURETOR ICING

There are three general classifications of carburetor icing that are common for all aircraft:

(1) Fuel evaporation ice.
(2) Throttle ice.
(3) Impact ice.

Fuel evaporation ice or refrigeration ice is formed because of the decrease in air temperature resulting from the evaporation of fuel after it is introduced into the airstream. It frequently occurs in those systems where the fuel is injected into the air upstream from the carburetor throttle, as in the case of float-type carburetors. It occurs less frequently in the systems in which the fuel is injected into the air downstream from the carburetor. Engines employing spinner or impeller injection of fuel are free of this type of ice, except those that have turning vanes (to change the direction of flow) at the entrance to the impeller. In this type, ice can be deposited on the turning vanes. Refrigeration ice can be formed at carburetor air temperatures as high as 100° F. over a wide range of atmospheric humidity conditions, even at relative humidities well below 100%. Generally, fuel evaporation ice will tend to accumulate on the fuel distribution nozzle, the turning vanes, and any protuberances in the carburetor. This type of ice can lower manifold pressure, interfere with fuel flow, and affect mixture distribution.

Throttle ice is formed on the rear side of the throttle, usually when the throttle is in a partially "closed" position. The rush of air across and around the throttle valve causes a low pressure on the rear side; this sets up a pressure differential across the throttle, which has a cooling effect on the fuel/air charge. Moisture freezes in this low-pressure area and collects as ice on the low-pressure side. Throttle ice tends to accumulate in a restricted passage. The occurrence of a small amount of ice may cause a relatively large reduction in airflow and manifold pressure. A large accumulation of ice may jam the throttles and cause them to become inoperable. Throttle ice seldom occurs at temperatures above 38° F.

Impact ice is formed either from water present in the atmosphere as snow, sleet, or subcooled liquid water, or from liquid water which impinges on surfaces that are at temperatures below 30° F. Because of inertia effects, impact ice collects on or near a surface that changes the direction of the airflow. This type of ice may build up on the carburetor elbow, as well as the carburetor screen and metering elements. The most dangerous impact ice is that which collects on the carburetor screen and causes a very rapid throttling of airflow and power. In general, danger from impact ice exists only when ice forms on the leading edges of the aircraft structure.

Under some conditions ice may enter the carburetor in a comparatively dry state and will not adhere to the screen or walls; therefore, it will not affect engine airflow or manifold pressure. This ice may enter the carburetor and gradually build up internally in the carburetor air metering passages and affect carburetor metering characteristics.

FLOAT-TYPE CARBURETORS

A float-type carburetor consists essentially of a main air passage through which the engine draws its supply of air, a mechanism to control the quantity of fuel discharged in relation to the flow of air, and a means of regulating the quantity of fuel/air mixture delivered to the engine cylinders.

The essential parts of a float-type carburetor are illustrated in figure 3–7. These parts are:

(1) The float mechanism and its chamber.
(2) The main metering system.
(3) The idling system.
(4) The mixture control system.
(5) The accelerating system.
(6) The economizer system.

Float Mechanism

A float chamber is provided between the fuel supply and the metering system of the carburetor. The float chamber provides a nearly constant level of fuel to the main discharge nozzle. This level is usually about 1/8 in. below the holes in the main discharge nozzle. The fuel level must be maintained slightly below the discharge nozzle outlet holes to provide the correct amount of fuel flow and to prevent fuel leakage from the nozzle when the engine is not operating.

The level of fuel in the float chamber is kept nearly constant by means of a float-operated needle valve and a seat. The needle seat is usually made of bronze. The needle valve is constructed of hardened steel, or it may have a synthetic rubber section which fits the seat. With no fuel in the float chamber, the float drops toward the bottom of the chamber and allows the needle valve to open wide. As fuel is admitted from the supply line, the float rises and closes the valve when the fuel reaches a predetermined level. When the engine is running and fuel is being drawn out of the float chamber, the valve assumes an intermediate position so that the valve opening is just sufficient to supply the required amount of fuel and keep the level constant.

With the fuel at the correct level, the discharge rate is controlled accurately by the air velocity through the carburetor and the atmospheric pressure on top of the fuel in the float chamber. A vent or small opening in the top of the float chamber allows air to enter or leave the chamber as the level

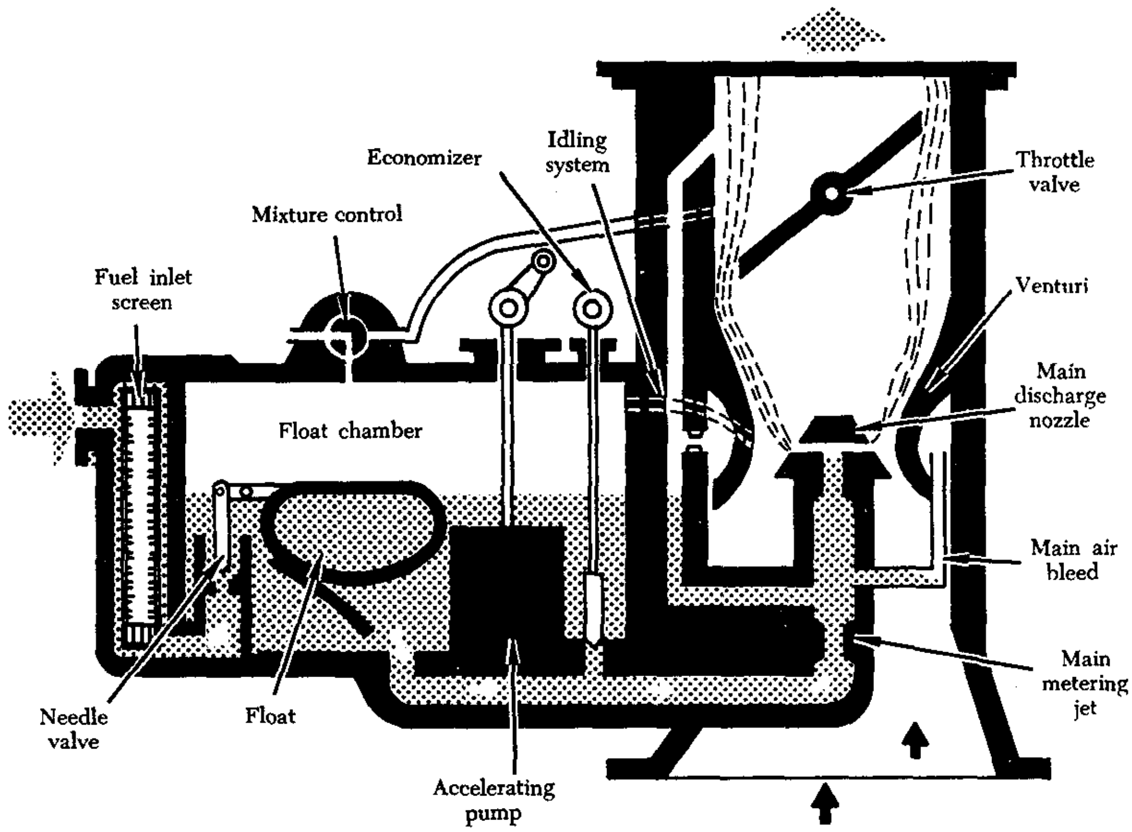


FIGURE 3–7. A float-type carburetor.

of fuel rises or falls. This vent passage is open into the engine air intake; thus, the air pressure in the chamber is always the same as that existing in the air intake.

Main Metering System

The main metering system supplies fuel to the engine at all speeds above idling and consists of:

(1) A venturi.
(2) A main metering jet.
(3) A main discharge nozzle.
(4) A passage leading to the idling system.
(5) The throttle valve.

Since the throttle valve controls the mass airflow through the carburetor venturi it must be considered a major unit in the main metering system as well as in other carburetor systems. A typical main metering system is illustrated in figure 3–8.

The venturi performs three functions: (1) Proportions the fuel/air mixture, (2) decreases the pressure at the discharge nozzle, and (3) limits the airflow at full throttle.

The fuel discharge nozzle is located in the carburetor barrel so that its open end is in the throat or narrowest part of the venturi.

A main metering orifice, or jet, is placed in the

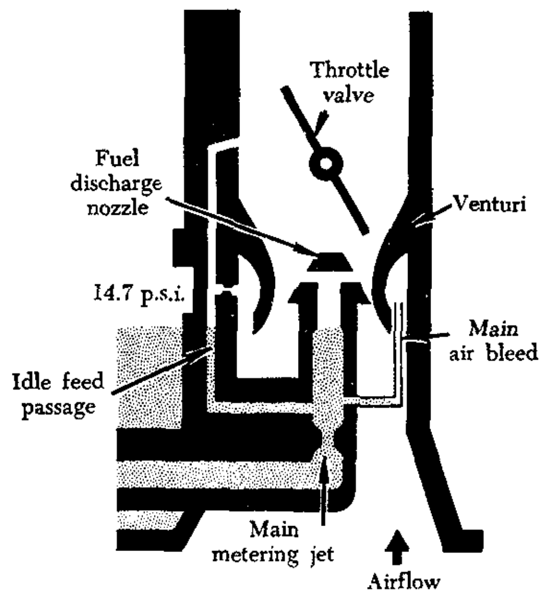


FIGURE 3–8. Main metering system.

fuel passage between the float chamber and the discharge nozzle to limit the fuel flow when the throttle valve is wide open.

When the engine crankshaft is revolved with the carburetor throttle open, the low pressure created in the intake manifold acts on the air passing through the carburetor barrel. Due to the difference in pressure between the atmosphere and the intake manifold, air will flow from the air intake through the carburetor barrel into the intake manifold. The volume of airflow depends upon the degree of throttle opening.

As the air flows through the venturi, its velocity increases. This velocity increase creates a low pressure area in the venturi throat. The fuel discharge nozzle is exposed to this low pressure. Since the float chamber is vented to atmospheric pressure, a pressure drop across the discharge nozzle is created. It is this pressure difference, or metering force, that causes fuel to flow from the discharge nozzle. The fuel comes out of the nozzle in a fine spray, and the tiny particles of fuel in the spray quickly vaporize in the air.

The metering force in most carburetors increases as the throttle opening is increased. A pressure drop of at least 0.5 in. Hg is required to raise the fuel in the discharge nozzle to a level where it will discharge into the airstream. At low engine speeds where the metering force is considerably reduced, the fuel delivery from the discharge nozzle would decrease if an air bleed (air metering jet) were not incorporated in the carburetor.

The decrease in fuel flow in relation to airflow is due to two factors: (1) The fuel tends to adhere to the walls of the discharge nozzle and break off intermittently in large drops instead of forming a fine spray, and (2) a part of the metering force is required to raise the fuel level from the float chamber level to the discharge nozzle outlet.

The basic principle of the air bleed can be explained by simple diagrams as shown in figure 3–9. In each case, the same degree of suction is applied to a vertical tube placed in the container of liquid. As shown in A, the suction applied on the upper end of the tube is sufficient to lift the liquid a distance of about 1 in. above the surface. If a small hole is made in the side of the tube above the surface of the liquid, as in B, and suction is applied, bubbles of air will enter the tube and the liquid will be drawn up in a continuous series of small slugs or drops. Thus, air "bleeds" into the tube and partially reduces the forces tending to retard the flow of liquid through the tube. However, the large opening at the bottom of the tube effectively prevents any great amount of suction from being exerted on the air bleed hole or vent. Similarly, an air bleed hole which is too large in proportion to the size of the tube would reduce the suction available to lift the liquid. If the system is modified by placing a metering orifice in the bottom of the tube and air is taken in below the fuel level by means of an air bleed tube, a finely divided emulsion of air and liquid is formed in the tube, as shown in C.

In a carburetor, a small air bleed is led into the fuel nozzle slightly below the fuel level. The open end of the air bleed is in the space behind the venturi wall, where the air is relatively motionless and approximately at atmospheric pressure. The

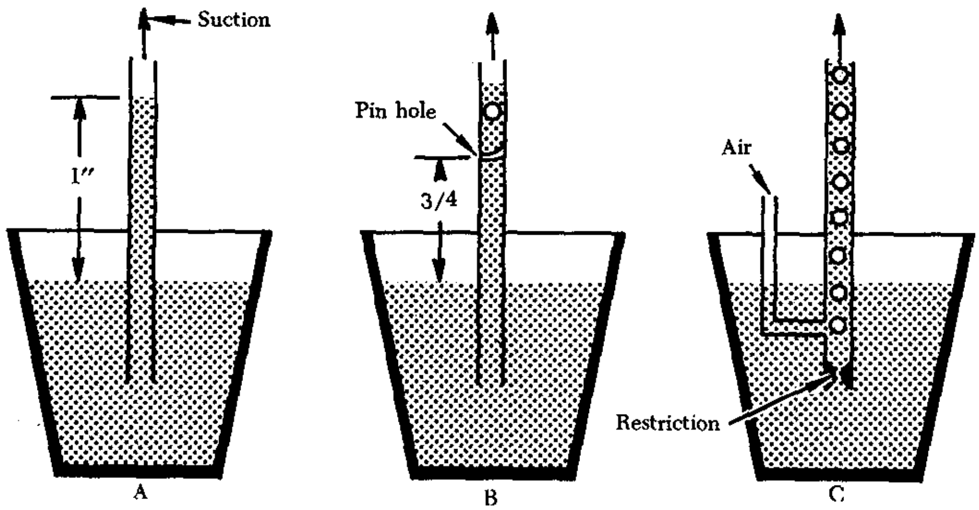


FIGURE 3–9. Air bleed principle.

low pressure at the tip of the nozzle not only draws fuel from the float chamber but also draws air from behind the venturi. Air bled into the main metering fuel system decreases the fuel density and destroys surface tension. This results in better vaporization and control of fuel discharge, especially at lower engine speeds.

The throttle, or butterfly valve, is located in the carburetor barrel near one end of the venturi. It provides a means of controlling engine speed or power output by regulating the airflow to the engine. This valve is a disk which can rotate on an axis, so that it can be turned to open or close the carburetor air passage. Where more than one throttle valve is necessary, they may be attached to the same throttle shaft or to separate shafts. In the latter case, it is necessary to check the uniformity of opening or synchronization.

Idling System

With the throttle valve closed at idling speeds, air velocity through the venturi is so low that it cannot draw enough fuel from the main discharge nozzle; in fact, the spray of fuel may stop altogether. However, low pressure (piston suction) exists on the engine side of the throttle valve. In order to allow the engine to idle, a fuel passageway is incorporated to discharge fuel from an opening in the low pressure area near the edge of the throttle valve. This opening is called the idling jet. With the throttle open enough so that the main discharge nozzle is operating, fuel does not flow out of the idling jet. As soon as the throttle is closed far enough to stop the spray from the main discharge nozzle, fuel flows out the idling jet. A separate air bleed, known as the idle air bleed, is included as part of the idling system. It functions the same as the main air bleed. An idle mixture adjusting device is also incorporated. A typical idling system is illustrated in figure 3–10.

Mixture Control System

As altitude increases, the air becomes less dense. At an altitude of 18,000 ft. the air is only half as dense as it is at sea level. This means that a cubic foot of space contains only half as much air at 18,000 ft. as at sea level. An engine cylinder full of air at 18,000 ft. contains only half as much oxygen compared to a cylinder full of air at sea level.

The low pressure area created by the venturi is dependent upon air velocity rather than air density. The action of the venturi draws the same volume of fuel through the discharge nozzle at a high altitude as it does at a low altitude. Therefore, the fuel mixture becomes richer as altitude increases. This can be overcome either by a manual or an automatic mixture control.

On float-type carburetors two types of purely manual or cockpit controllable devices are in general use for controlling fuel/air mixtures, the needle type and the back-suction type. The two types are illustrated in figures 3–11 and 3–12.

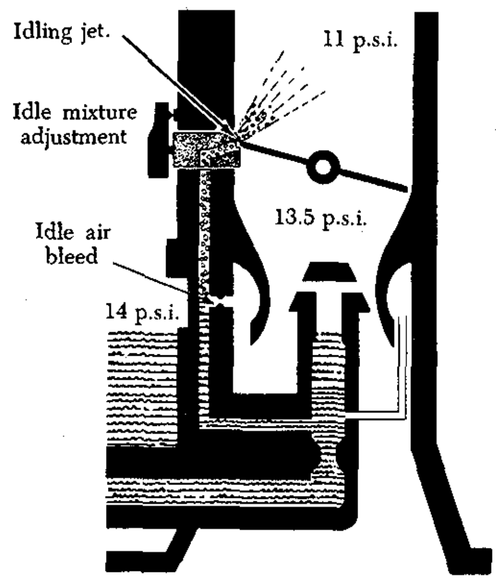


FIGURE 3–10. Idling system.

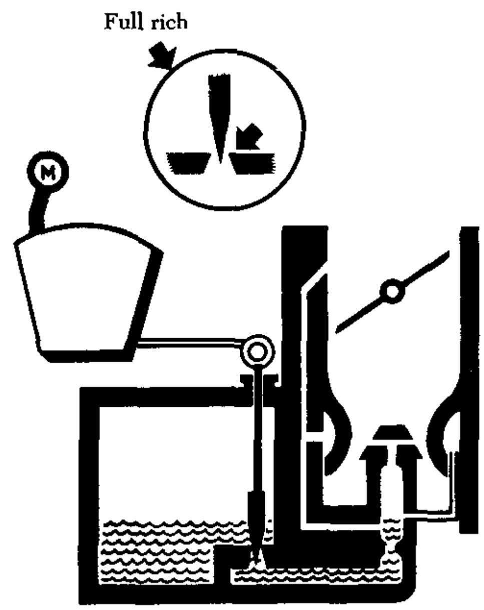


FIGURE 3–11. Needle-type mixture control system.

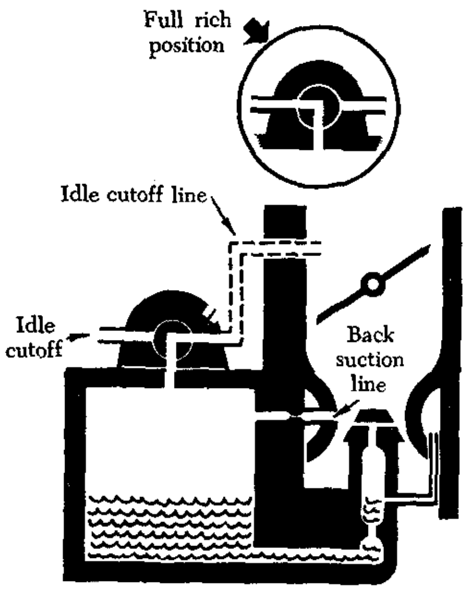


FIGURE 3–12. Back-suction type mixture control system.

With the needle-type system, manual control is provided by a needle valve in the base of the float chamber (figure 3–11). This can be raised or lowered by adjusting a control in the cockpit. Moving the control to "rich" opens the needle valve wide, which permits the fuel to flow unrestricted to the nozzle. Moving the control to "lean" closes the valve part way and restricts the flow of fuel to the nozzle.

The back-suction type mixture control system is the most widely used. In this system (figure 3–12) a certain amount of venturi low pressure acts upon the fuel in the float chamber so that it opposes the low pressure existing at the main discharge nozzle. An atmospheric line, incorporating an adjustable valve, opens into the float chamber. When the valve is completely closed, pressures on the fuel in the float chamber and at the discharge nozzle are almost equal and fuel flow is reduced to maximum lean. With the valve wide open, pressure on the fuel in the float chamber is greatest and fuel mixture is richest. Adjusting the valve to positions between these two extremes controls the mixture.

The quadrant in the cockpit is usually marked "lean" near the back end and "rich" at the forward end. The extreme back position is marked "idle cutoff" and is used when stopping the engine.

On float carburetors equipped with needle-type mixture control, placing the mixture control in idle cutoff seats the needle valve, thus shutting off fuel flow completely. On carburetors equipped with back-suction mixture controls, a separate idle cutoff line, leading to the extreme low pressure on the engine side of the throttle valve, is incorporated. (See the dotted line in figure 3–12.) The mixture control is so linked that when it is placed in the "idle cutoff" position, it opens another passage which leads to piston suction; when placed in other positions, the valve opens a passage leading to the atmosphere. To stop the engine with such a system, close the throttle and place the mixture in the "idle cutoff" position. Leave the throttle closed until the engine has stopped turning over and then open the throttle completely.

Accelerating System

When the throttle valve is opened quickly, a large volume of air rushes through the air passage of the carburetor. However, the amount of fuel that is mixed with the air is less than normal. This is because of the slow response rate of the main metering system. As a result, after a quick opening of the throttle, the fuel/air mixture leans out momentarily.

To overcome this tendency, the carburetor is equipped with a small fuel pump called an accelerating pump. A common type of accelerating system used in float carburetors is illustrated in figure 3–13. It consists of a simple piston pump operated through linkage, by the throttle control, and a line opening into the main metering system or the carburetor barrel near the venturi. When the throttle is closed, the piston moves back and fuel fills the cylinder. If the piston is pushed forward slowly, the fuel seeps past it back into the float chamber, but if pushed rapidly, it will emit a charge of fuel and enrich the mixture in the venturi.

Economizer System

For an engine to develop maximum power at full throttle, the fuel mixture must be richer than for cruise. The additional fuel is used for cooling the engine to prevent detonation. An economizer is essentially a valve which is closed at throttle settings below approximately 60 to 70% of rated power. This system, like the accelerating system, is operated by the throttle control.

A typical economizer system, as shown in figure 3–14, consists of a needle valve which begins to open when the throttle valve reaches a predetermined point near the wide-open position. As the throttle continues to open, the needle valve is opened further and additional fuel flows through it. This additional fuel supplements the flow from the main metering jet direct to the main discharge nozzle.

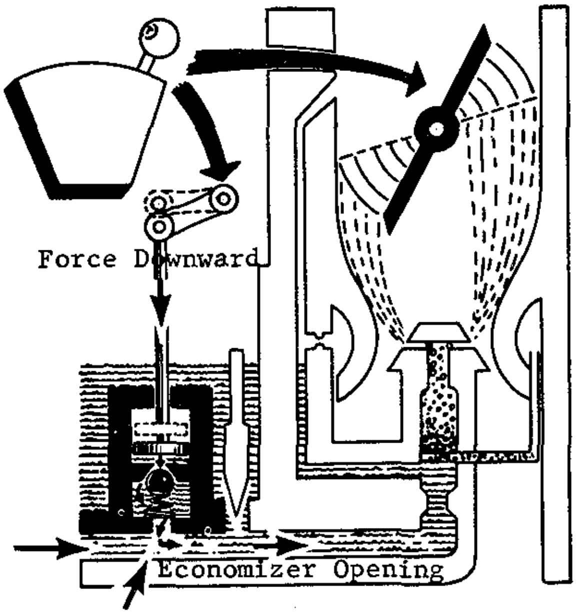


FIGURE 3–13. Accelerating system.

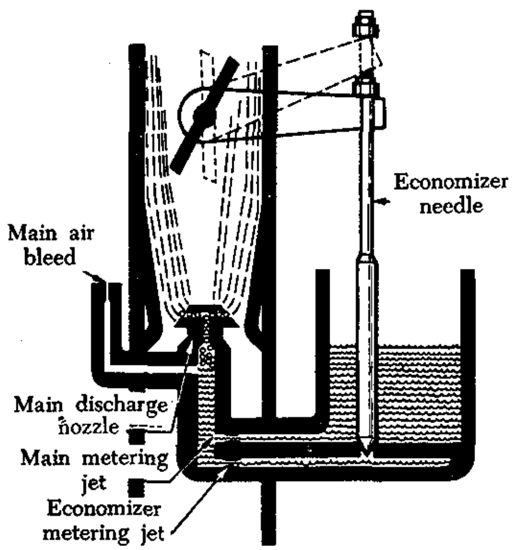


FIGURE 3–14. A needle-valve type economizer system.

A pressure-operated economizer system is shown in figure 3–15. This type has a sealed bellows located in an enclosed compartment. The compartment is vented to engine manifold pressure. When the manifold pressure reaches a certain value, the bellows is compressed and opens a valve in a carburetor fuel passage, supplementing the normal quantity of fuel being discharged through the main nozzle.

Another type of economizer is the back-suction system shown in figure 3–16. Fuel economy in

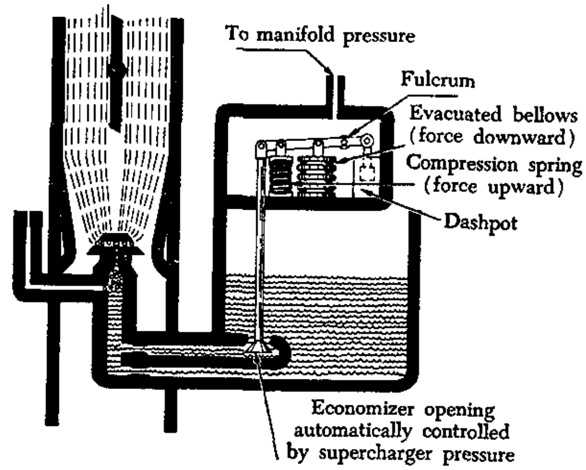


FIGURE 3–15. A pressure-operated economizer system.

cruising is provided by reducing the effective pressure acting on the fuel level in the float compartment. With the throttle valve in cruising position, suction is applied to the float chamber through an economizer hole and back-suction economizer channel and jet. The suction thus applied to the float chamber opposes the nozzle suction applied by the venturi. Fuel flow is reduced, thus leaning the mixture for cruising economy.

Another type mixture control system uses a metering valve which is free to rotate in a stationary metering sleeve. Fuel enters the main and idling systems through a slot cut in the mixture sleeve. Fuel metering is accomplished by the relative position between one edge of the slot in the hollow metering valve and one edge of the slot in the metering sleeve. Moving the mixture control to reduce the size of the slot provides a leaner mixture for altitude compensation.

PRESSURE INJECTION CARBURETORS

Pressure injection carburetors are distinctly different from float-type carburetors, as they do not incorporate a vented float chamber or suction pickup from a discharge nozzle located in the venturi tube. Instead, they provide a pressurized fuel system that is closed from the engine fuel pump to the discharge nozzle. The venturi serves only to create pressure differentials for controlling the quantity of fuel to the metering jet in proportion to airflow to the engine.

Typical Injection Carburetor

The injection carburetor is a hydromechanical device employing a closed feed system from the fuel

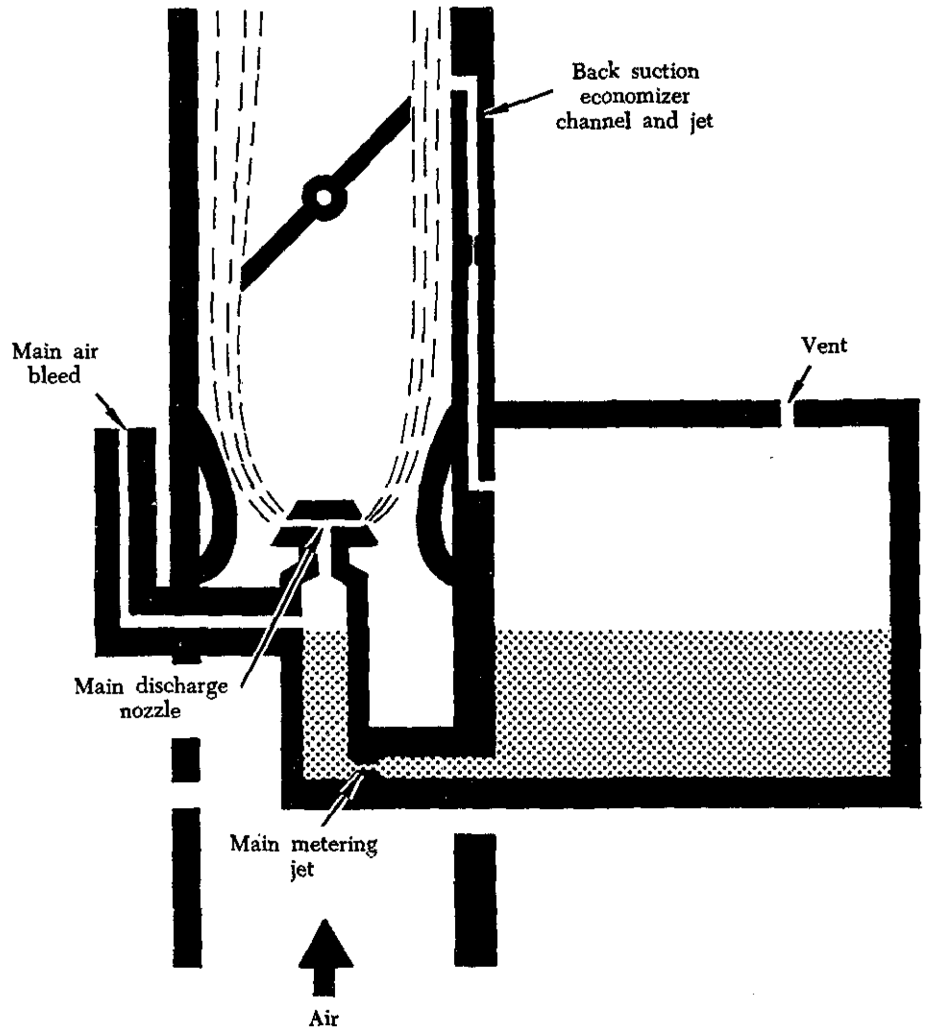


FIGURE 3–16. Back-suction economizer system.

pump to the discharge nozzle. It meters fuel through fixed jets according to the mass airflow through the throttle body and discharges it under a positive pressure.

The illustration in figure 3–17 represents a pressure-type carburetor simplified to the extent that only the basic parts are shown. Note the two small passages, one leading from the carburetor air inlet to the left side of the flexible diaphragm and the other from the venturi throat to the right side of the diaphragm.

When air passes through the carburetor to the engine, the pressure on the right of the diaphragm is lowered because of the drop in pressure at the venturi throat. As a result, the diaphragm moves to the right, opening the fuel valve. Pressure from the engine-driven pump then forces fuel through the open valve to the discharge nozzle, where it sprays into the airstream. The distance the fuel valve opens is determined by the difference between the two pressures acting on the diaphragm. This difference in pressure is proportional to the airflow through the carburetor. Thus, the volume of airflow determines the rate of fuel discharge.

The pressure injection carburetor is an assembly of the following units:

(1) Throttle body.
(2) Automatic mixture control.
(3) Regulator unit.
(4) Fuel control unit; some are equipped with an adapter.

Throttle Body

The throttle body contains the throttle valves, main venturi, boost venturi, and the impact tubes. All air entering the cylinders must flow through the

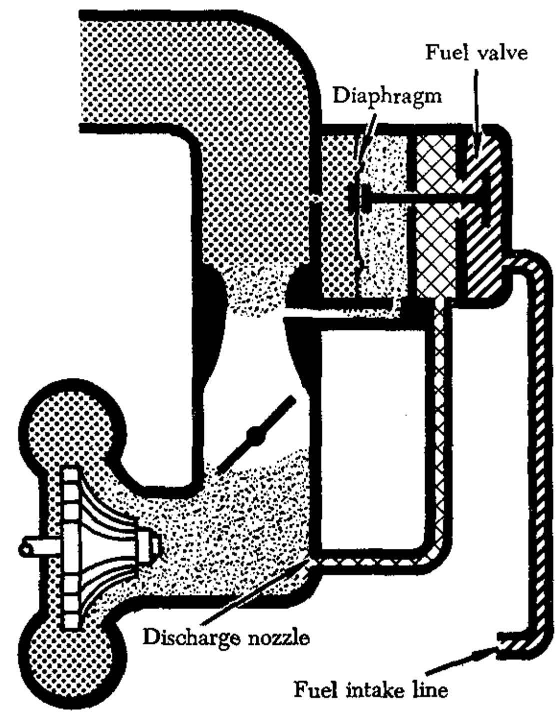


FIGURE 3–17. Pressure-type carburetor.

throttle body; therefore, it is the air control and measuring device. The airflow is measured by volume and by weight so that the proper amount of fuel can be added to meet the engine demands under all conditions.

As air flows through the venturis, its velocity is increased and its pressure is decreased (Bernoulli's principle). This low pressure is vented to the low-pressure side of the air diaphragm (chamber B, figure 3–18), in the regulator assembly. The impact tubes sense carburetor inlet air pressure and direct it to the automatic mixture control, which measures the air density. From the automatic mixture control the air is directed to the high-pressure side of the air diaphragm (chamber A). The pressure differential of the two chambers acting upon the air diaphragm is known as the air metering force which opens the fuel poppet valve.

The throttle body controls the airflow with the throttle valves. The throttle valves may be either rectangular or disk shaped, depending on the design of the carburetor. The valves are mounted on a shaft which is connected by linkage to the idle valve and to the throttle control in the cockpit. A throttle stop limits the travel of the throttle valve and has an adjustment which sets engine idle speed.

Regulator Unit

The regulator (figure 3–18) is a diaphragm-controlled unit which is divided into five chambers and

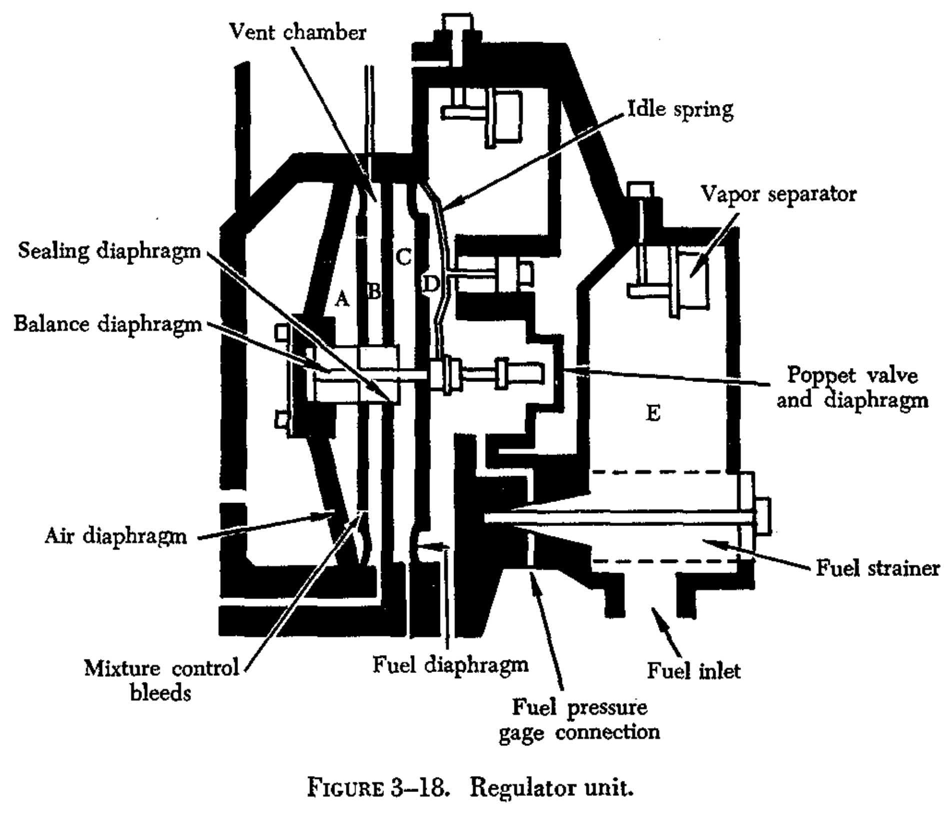


FIGURE 3–18. Regulator unit.

contains two regulating diaphragms and a poppet valve assembly. Chamber A is regulated air-inlet pressure from the air intake. Chamber B is boost venturi pressure. Chamber C contains metered fuel pressure controlled by the discharge nozzle or fuel feed valve. Chamber D contains unmetered fuel pressure controlled by the opening of the poppet valve. Chamber E is fuel pump pressure, controlled by the fuel pump pressure relief valve. The poppet valve assembly is connected by a stem to the two main control diaphragms.

The carburetor fuel strainer, located in the inlet to chamber E, is a fine mesh screen through which all the fuel must pass as it enters chamber D. The strainer must be removed and cleaned at scheduled intervals.

The purpose of the regulator unit is to regulate the fuel pressure to the inlet side of the metering jets in the fuel control unit. This pressure is automatically regulated according to the mass airflow to the engine.

Referring to figure 3–18, assume that for a given airflow in lbs./hr. through the throttle body and venturi, a negative pressure of one-fourth p.s.i. is established in chamber B. This tends to move the diaphragm assembly and the poppet valve in a direction to open the poppet valve, permitting more fuel to enter chamber D. The pressure in chamber C is held constant at 5 p.s.i. (10 p.s.i. on some installations) by the discharge nozzle or impeller fuel feed valve. Therefore, the diaphragm assembly and poppet valve will move in the open direction until the pressure in chamber D is 5-1/4 p.s.i. Under these pressures, there is a balanced condition of the diaphragm assembly with a pressure drop of one-fourth p.s.i. across the jets in the fuel control unit (auto-rich or auto-lean).

Fuel Control Unit

The fuel control unit (figure 3–19) is attached to the regulator assembly and contains all metering jets and valves. The idle and power enrichment valves, together with the mixture control plates, select the jet combinations for the various settings, i.e., auto-rich, auto-lean, and idle cutoff.

If nozzle pressure (chamber C pressure) rises to 5-1/2 p.s.i., the diaphragm assembly balance will be upset, and the diaphragm assembly will move to open the poppet valve to establish the necessary 5-3/4 p.s.i. pressure in chamber D. Thus, the one-fourth p.s.i. differential between chamber C and chamber D is re-established, and the pressure drop across the metering jets will remain the same.

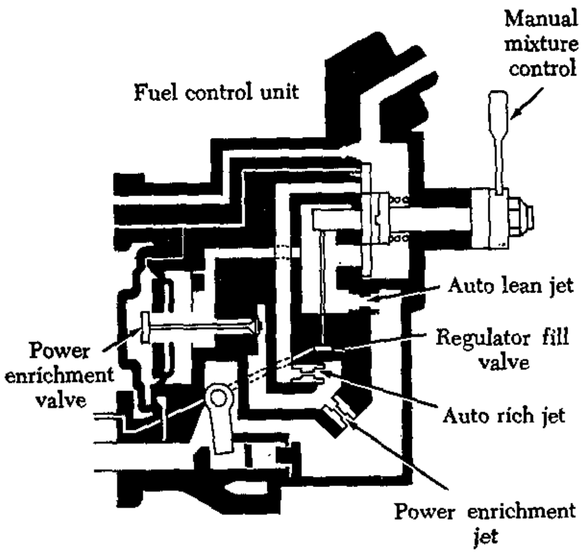


FIGURE 3–19. Fuel control unit.

If the fuel inlet pressure is increased or decreased, the fuel flow into chamber D will tend to increase or decrease with the pressure change, causing the chamber D pressure to do likewise. This will upset the balanced condition previously established, and the poppet valve and diaphragm assembly will respond by moving to increase or decrease the flow to re-establish the pressure at the one-fourth p.s.i. differential.

When the mixture control plates are moved from auto-lean to auto-rich or vice versa, thereby selecting a different set of jets or cutting one or two in or out of the system, the fuel flow changes. However, when the mixture position is altered, the diaphragm and poppet valve assembly will reposition to maintain the established pressure differential of one-fourth p.s.i. between chambers C and D, maintaining the established differential across the jets.

Under low-power settings (low airflows), the difference in pressure created by the boost venturi is not sufficient to accomplish consistent regulation of the fuel. Therefore, an idle spring, shown in figure 3–18, is incorporated in the regulator. As the poppet valve moves toward the closed position, it contacts the idle spring. The spring holds the poppet valve off its seat far enough to provide more fuel than is needed for idling. This potentially over-rich mixture is regulated by the idle valve. At idling speed the idle valve restricts the fuel flow to the proper amount. At higher speeds it is withdrawn from the fuel passage and has no metering effect.

Vapor vent systems are provided in these carburetors to eliminate fuel vapor created by the fuel pump, heat in the engine compartment, and the pressure drop across the poppet valve. The vapor vent is located in the fuel inlet (chamber E) or, on some models of carburetors, in both chambers D and E.

The vapor vent system operates in the following way. When air enters the chamber in which the vapor vent is installed, the air rises to the top of the chamber, displacing the fuel and lowering its level. When the fuel level has reached a predetermined position, the float (which floats in the fuel) pulls the vapor vent valve off its seat, permitting the vapor in the chamber to escape through the vapor vent seat, its connecting line, and back to the fuel tank.

If the vapor vent valve sticks in a closed position or the vent line from the vapor vent to the fuel tank becomes clogged, the vapor-eliminating action will be stopped. This will cause the vapor to build up within the carburetor to the extent that vapor will pass through the metering jets with the fuel. With a given-size carburetor metering jet, the metering of vapor will reduce the quantity of fuel metered. This will cause the fuel/air mixture to lean out, usually intermittently.

If the vapor vent valve sticks open or the vapor vent float becomes filled with fuel and sinks, a continuous flow of fuel and vapor occurs through the vent line. It is important to detect this condition, as the fuel flow from the carburetor to the fuel supply tank may cause an overflowing tank with resultant increased fuel consumption.

To check the vent system, disconnect the vapor vent line where it attaches to the carburetor, and turn the fuel booster pump on while observing the vapor vent connection at the carburetor. Move the carburetor mixture control to auto-rich; then return it to idle cutoff. When the fuel booster pump is turned on, there should be an initial ejection of fuel and air followed by a cutoff with not more than a steady drip from the vent connection. On installations where a fixed bleed from the D chamber is connected to the vapor vent in the fuel inlet by a short external line, there should be an initial ejection of fuel and air followed by a continuing small stream of fuel. If there is no flow, the valve is sticking closed; if there is a steady flow, it is sticking open.

The purpose of the fuel control unit is to meter and control the fuel flow to the discharge nozzle. The basic unit consists of three jets and four valves arranged in series, parallel, and series-parallel hookups. (See figure 3–19.) These jets and valves receive fuel under pressure from the regulator unit and then meter the fuel as it goes to the discharge nozzle. The manual mixture control valve controls the fuel flow. By using proper size jets and regulating the pressure differential across the jets, the right amount of fuel is delivered to the discharge nozzle, giving the desired fuel/air ratio in the various power settings. It should be remembered that the inlet pressure to the jets is regulated by the regulator unit and the outlet pressure is controlled by the discharge nozzle.

The jets in the basic fuel control unit are the auto-lean jet, the auto-rich jet, and power enrichment jet. The basic fuel flow is the fuel required to run the engine with a lean mixture and is metered by the auto-lean jet. The auto-rich jet adds enough fuel to the basic flow to give a slightly richer mixture than best power mixture when the manual mixture control is in the "auto-rich" position.

The four valves in the basic fuel control unit are:

(1) The idle needle valve.
(2) The power enrichment valve.
(3) The regulator fill valve.
(4) The manual mixture control.

The functions of these valves are as follows:

(1) The idle needle valve meters the fuel in the idle range only. It is a round, contoured needle valve or a cylinder valve placed in series with all other metering devices of the basic fuel control unit. The idle needle valve is connected by linkage to the throttle shaft so that it will restrict the fuel flowing at low-power settings (idle range).
(2) The manual mixture control is a rotary disk valve consisting of a round stationary disk with ports leading from the auto-lean jet, the auto-rich jet, and two smaller ventholes. Another rotating part, resembling a cloverleaf, is held against the stationary disk by spring tension and rotated over the ports in that disk by the manual mixture control lever. All ports and vents are closed in the "idle cutoff" position. In the "auto-lean" position, the ports from the auto-lean jet and the two ventholes are open. The port from the auto-rich jet remains closed in this position. In the "auto-rich" position, all ports are open. The valve plate positions are illustrated in figure 3–20. The three positions of the manual mixture control lever make it possible to select a lean mixture or a rich mixture, or to stop fuel flow

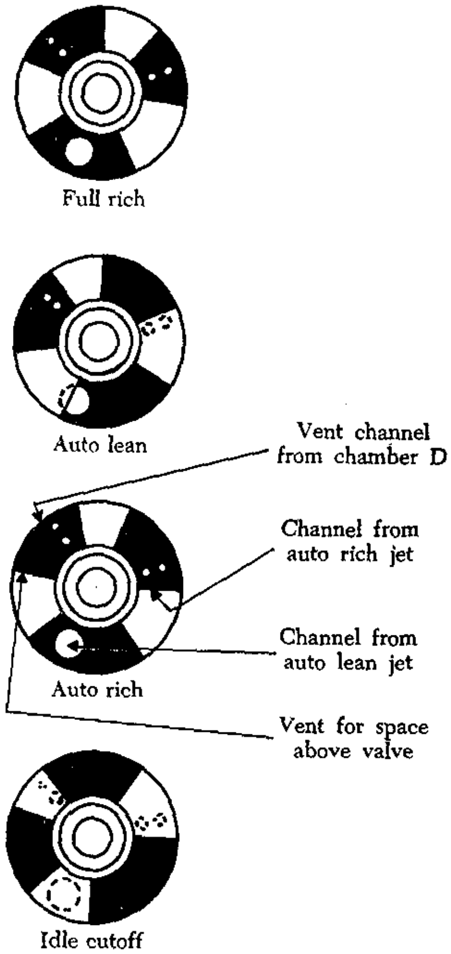


FIGURE 3–20. Manual mixture control valve plate positions.

entirely. The "idle cutoff" position is used for starting or stopping the engine. During starting, fuel is supplied by the primer.

(3) The regulator fill valve is a small poppet-type valve located in a fuel passage which supplies chamber C of the regulator unit with metered fuel pressure. In idle cutoff, the flat portion of the cam lines up with the valve stem, and a spring closes the valve. This provides a means of shutting off the fuel flow to chamber C and thus provides for a positive idle cutoff.

(4) The power enrichment valve is another poppet-type valve. It is in parallel with the auto-lean and auto-rich jets, but it is in series with the power enrichment jet. This valve starts to open at the beginning of the power range. It is opened by the unmetered fuel pressure overcoming metered fuel pressure and spring tension. The power enrichment valve continues to open wider and wider during the power range until the combined flow through the valve and the auto-rich jet exceeds that of the power enrichment jet. At this point the power enrichment jet takes over the metering and meters fuel throughout the power range.

(5) Carburetors equipped for water injection are modified by the addition of a derichment valve and a derichment jet. The derichment valve and derichment jet are in series with each other and parallel with the power enrichment jet.

The carburetor controls fuel flow by varying two basic factors. The fuel control unit, acting as a pressure-reducing valve, determines the metering pressure in response to the metering forces. The regulator unit, in effect, varies the size of the orifice through which the metering pressure forces the fuel. It is a basic law of hydraulics that the amount of fluid that passes through an orifice varies with the size of the orifice and the pressure drop across it. The internal automatic devices and mixture control act together to determine the effective size of the metering passage through which the fuel passes. The internal devices, fixed jets, and variable power enrichment valve are not subject to direct external control.

Automatic Mixture Control (AMC)

The automatic mixture control unit (figure 3–21)

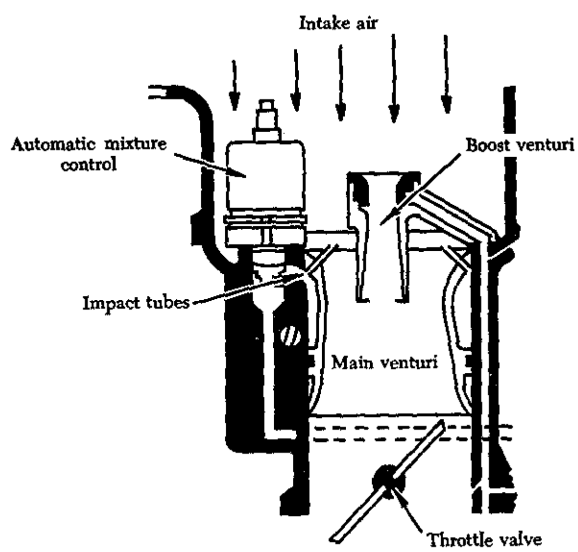


FIGURE 3–21. Automatic mixture control and throttle body.

consists of a bellows assembly, calibrated needle, and seat. The purpose of the automatic mixture control is to compensate for changes in air density due to temperature and altitude changes.

The automatic mixture control contains a metallic bellows, sealed at 28 in. Hg, absolute pressure, which responds to changes in pressure and temperature. In the illustration, note that the automatic mixture control is located at the carburetor air inlet. As the density of the air changes, the expansion and contraction of the bellows moves the tapered needle in the atmospheric line. At sea level, the bellows is contracted and the needle is not in the atmospheric passage. As the aircraft climbs and the atmospheric pressure decreases, the bellows expands, inserting the tapered needle farther and farther into the atmospheric passage and restricting the flow of air to chamber A of the regulator unit (figure 3–18). At the same time, air leaks slowly from chamber A to chamber B through the small bleed (often referred to as the back-suction bleed, or mixture control bleed). The rate at which air leaks through this bleed is about the same at high altitude as it is at sea level. Thus, as the tapered needle restricts the flow of air into chamber A, the pressure on the left side of the air diaphragm decreases; as a result, the poppet valve moves toward its seat, reducing the fuel flow to compensate for the decrease in air density. The automatic mixture control can be removed and cleaned, provided the lead seal at the point of adjustment is not disturbed.

Adapter Unit

The purpose of the adapter is to adapt the carburetor to the engine. This unit may also contain the discharge nozzle and the accelerating pump (see figure 3–22). On engines using fuel feed valves, however, the discharge nozzle is eliminated, since the fuel feed valve serves the same purpose and is built into the engine. Where a spinner injection discharge valve is used in place of the discharge nozzle, the accelerating pump is usually housed on the side of the throttle body, and the adapter is then nothing more than a spacer and has no working parts.

The discharge nozzle is a spring-loaded valve which maintains metered fuel pressure. Before fuel can pass through the discharge nozzle, enough pressure must be built up against the diaphragm to overcome the tension of the spring which is on the air side of the diaphragm. The diaphragm then rises, lifting the attached valve, and the fuel is sprayed out the nozzle. Secured to the nozzle is a diffuser which

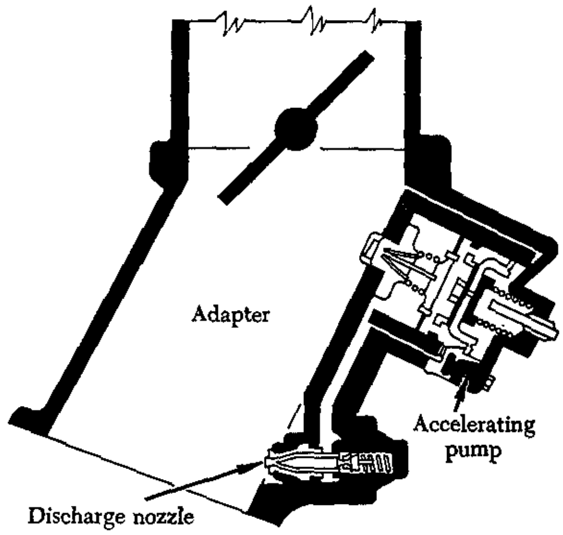


FIGURE 3–22. Adapter.

is designed to improve distribution and atomization of the fuel into the airstream. There are three types of diffusers used in adapter-mounted discharge nozzles—the rake, the bar, and the bow tie. Two other diffusers built into some engines are the slinger ring used with the fuel feed valve and the spinner ring used with the spinner injection discharge valve.

The acceleration pump is used to compensate for the inherent lag in fuel flow during rapid acceleration of the engine.

Pressure Injection Carburetor Systems

The pressure-type carburetor, like the float-type carburetor, contains a main metering system, an idling system, an accelerating system, a mixture control system (both manual and automatic), an idle cutoff system, and a power enrichment system. A schematic representation of a pressure injection carburetor, PD series, is illustrated in figure 3–23.

Main Metering System

Perhaps the most noticeable feature of the main metering system is the double venturi. In figure 3–23, note that the lower opening of the boost venturi is near the throat of the main one. Thus, the drop in pressure within the main venturi causes an acceleration in airflow through the boost venturi and, consequently, a still greater pressure drop at its throat. As a result, a greater differential in pressure and a greater air metering force are obtained.

To make use of this metering force, the throat of the boost venturi and the inlet to the main venturi are connected to the air chambers of the carburetor. There are two of these air chambers, A and B.

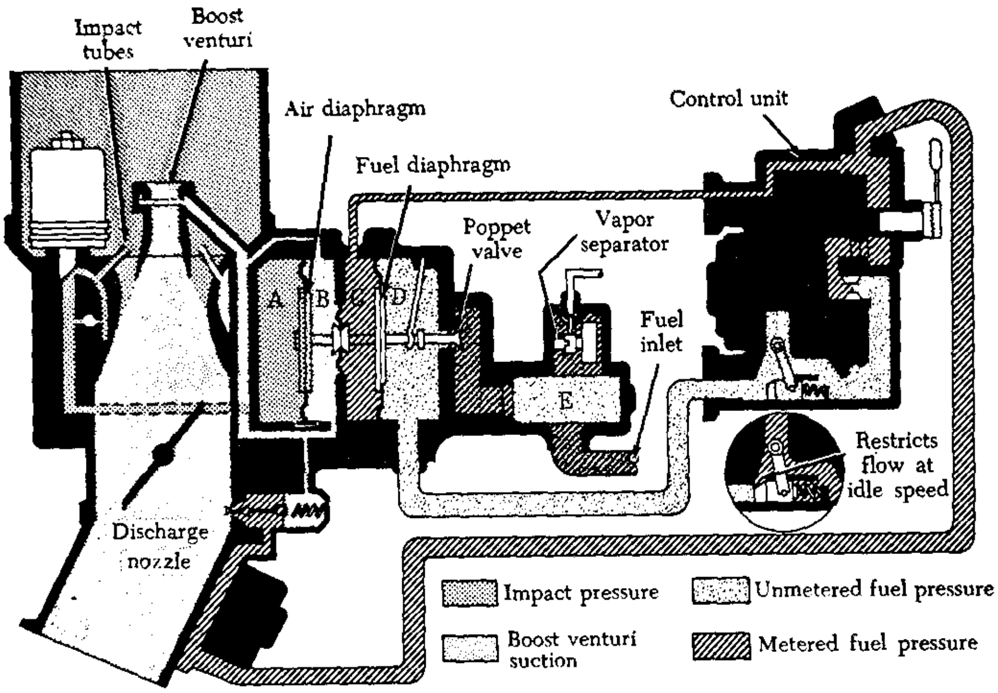


FIGURE 3–23. Schematic representation of a pressure injection carburetor, PD series.

Chambers C and D are fuel chambers. The passages from chamber B to the throat of the boost venturi can be easily traced. The other passage is less direct. It leads from chamber A to the space behind the main venturi. The impact tubes vent this space to the pressure at the carburetor air inlet. In some induction systems, the pressure at the carburetor air inlet is slightly above atmospheric because of ram effect. If there is a turbo or other supercharger ahead of the carburetor, the inlet pressure is considerably higher than atmospheric under certain operating conditions.

In all systems, the drop in pressure at the throat of the boost venturi is proportional to the airflow. This causes a lowering of the pressure in chamber B. Thus the pressures in the two air chambers differ, impact pressure in chamber A and boost venturi suction in chamber B. This pressure difference is a measure of airflow. The air-chamber diaphragm moves in the direction of the lower pressure (to the right), opening the poppet valve. This allows fuel, delivered to the carburetor inlet under pressure from the engine-driven pump, to enter chamber D. This fuel passes through the control unit to the discharge nozzle, where it forces the valve off its seat and sprays into the airstream. The pressure in the fuel discharge line is determined by setting of the nozzle. The pressure at which the engine-driven pump delivers fuel to the carburetor varies with different models. However, it is always well above the discharge nozzle setting.

Chamber C is filled with fuel at the same pressure as that in the discharge line. The function of chamber C is to allow fuel to be discharged under pressure and to compensate for variations of pressures in the discharge line. The discharge nozzle acts as a relief valve to hold this pressure relatively constant regardless of the volume of fuel being discharged. *This metered fuel pressure acts on the left side of the* fuel diaphragm. The fuel admitted to chamber D through the poppet valve exerts pressure against the opposite side of the diaphragm. The unmetered fuel pressure in chamber D varies with the position of the poppet valve and the rate of fuel discharge. During engine operation, it is higher than that in chamber C. Thus, there are two forces acting on the poppet valve: (1) A force on the air diaphragm (difference in pressure between chambers A and B) tending to open the valve, and (2) a force on the fuel diaphragm (difference in pressures between chambers D and C) tending to close the valve. The poppet valve moves toward the open position until the fuel pressure in chamber D is high enough to make these forces balance. This balance is reached when the fuel discharge and the airflow are in the correct proportion.

To prevent air in the fuel from upsetting the metering of the carburetor, there is a vapor separator at the fuel inlet. A small float and needle valve are positioned in the vapor separator chamber. When there are no vapors in the chamber, the float is raised and holds the needle valve closed. As vapors gather, the fuel level in the chamber drops, lowering the float until the needle valve opens. The vapors then escape through the vent line to one of the fuel tanks. This action is not an opening and closing process, but one in which the needle takes an intermediate position which allows vapors to escape as fast as they gather.

Idling System

In the pressure-type carburetor, the fuel follows the same path at idling as it does when the main metering system is in operation. Because of the low velocity of the air through the venturi, however, the differential pressure on the air diaphragm is not sufficient to regulate the fuel flow. Instead, the idle spring in chamber D holds the poppet valve off its seat to admit fuel from the carburetor inlet during operation at idling speeds. The inset in figure 3–23 shows how the idle valve meters this fuel from chamber D to the discharge nozzle. This valve is connected to the throttle linkage in such a manner that it regulates the fuel flow only during the first few degrees of throttle opening. At higher speeds, it is withdrawn from the fuel passage and has no metering effect.

Accelerating System

The accelerating pump is entirely automatic in operation. In the illustration in figure 3–24, note that the vacuum passage connects the pump vacuum chamber with the air passage at the engine side of the throttle valve. The air pressure at the engine side of the throttle valve varies with the throttle position. When the throttle is nearly closed and is restricting the airflow to the engine, the pressure is low because of piston suction. In the left-hand drawing, the throttle is nearly closed, and, as a result, the low pressure in the vacuum chamber has caused the diaphragm to move to the right. This compresses the spring and stores fuel on the left side of the diaphragm. When the throttle is opened, the pressure on the engine side of the throttle valve increases. As a result, the low pressure in the vacuum chamber is lost, and the spring moves the diaphragm to the left, discharging the fuel stored during the lower throttle setting. This fuel, added to that from the main metering system, compensates for the sudden increase in airflow and gives smooth acceleration.

Mixture Control System

The mixture control system contains both automatic and manually operated units. The automatic mixture control varies the air pressure in chamber A to compensate for changes in air density. The manual mixture control provides for selecting the fuel/air ratio to fit engine operating conditions.

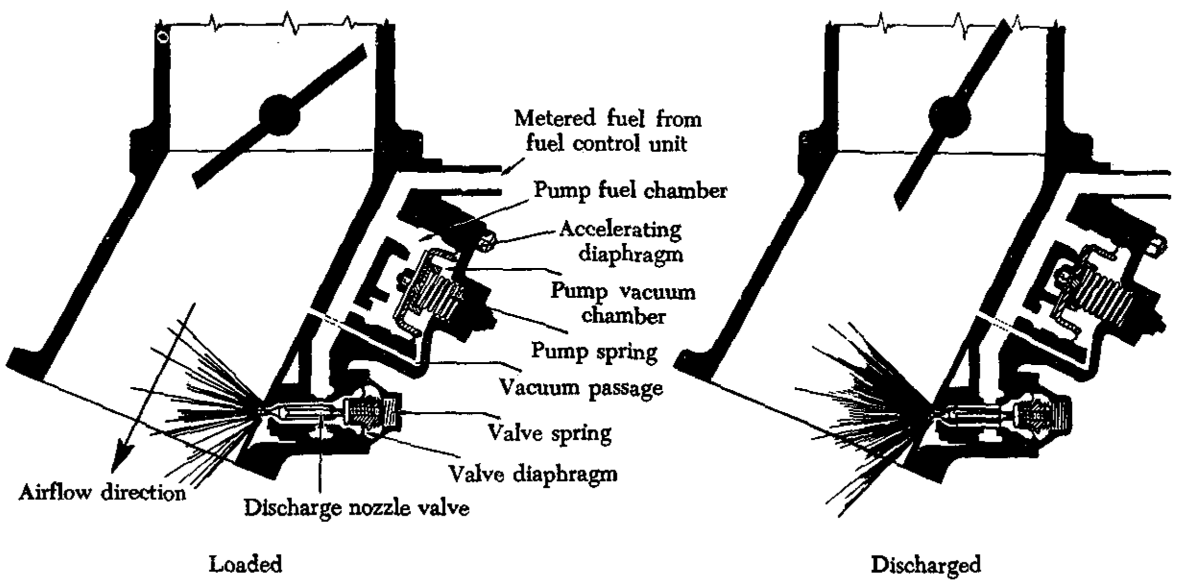
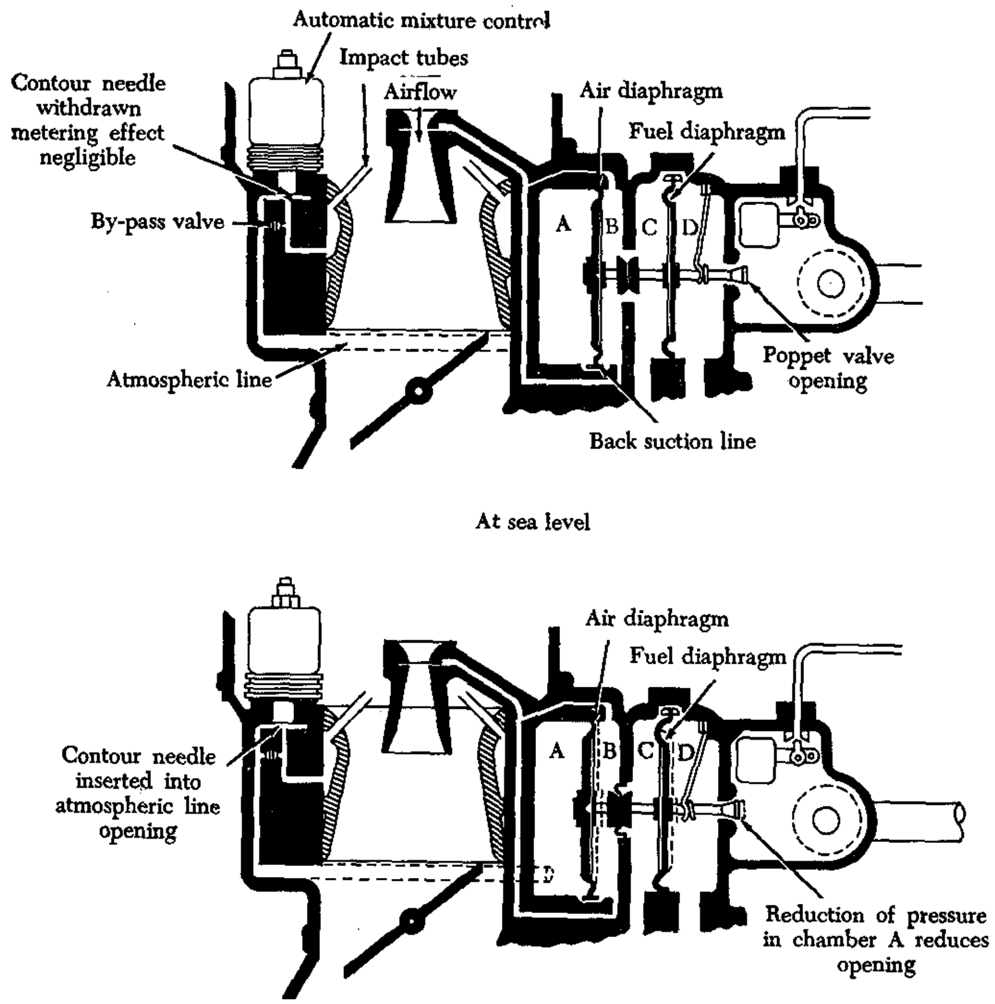


FIGURE 3–24. A single-diaphragm accelerating pump.

The automatic mixture control contains a sealed, metallic bellows, which responds to changes in pressure and temperature. As the density of the air changes, the expansion and contraction of the bellows moves the tapered needle in the atmospheric line. At sea level, the bellows is contracted and the needle is withdrawn from the atmospheric passage. Refer to the illustration showing the sea level condition in figure 3–25. As the aircraft climbs and the atmospheric pressure decreases, the bellows expands, inserting the tapered needle farther and farther into the atmospheric passage and restricting the flow of air to chamber A. At the same time, air leaks slowly from chamber A to chamber B through the small bleed. Thus, as the tapered needle restricts the flow of air into chamber A, the pressure on the left side of the air diaphragm decreases; as a result, the poppet valve moves toward its seat, reducing the fuel flow to compensate for the decrease in air density.

In the illustration of the manual mixture control, figure 3–23, note that fuel enters the control unit from chamber D, passes through it, and out to the discharge nozzle. The path of the fuel through the control unit is determined by the cloverleaf valve. The movable disk of this valve is rotated from the cockpit by means of a mixture control lever, which is linked to the lever on the carburetor.

The position that the movable disk takes when the cockpit control is set to auto-lean is shown in figure 3–26. Note that the large opening in the fixed disk is partially uncovered. This allows the fuel delivered to the control unit from chamber D to pass through the auto-lean metering jet, the auto-lean



At altitude

FIGURE 3–25. Automatic mixture control system.

channel, and the opening in the fixed disk into the discharge line. The rate of flow depends on the size of the jet and the fuel pressure from chamber D. The cloverleaf valve has no metering effect since the opening in the fixed disk is larger than the metering jet.

In figure 3–27 note that, in the "auto-rich" setting, the movable disk uncovers two additional openings in the fixed disk. Fuel then flows into the discharge line through both the automatic lean and the automatic rich metering jets. Thus, for each pressure, the fuel flow increases and a richer mixture is supplied to the engine.

In all mixture settings, the position of the movable disk determines which jets will meter the fuel. The fuel discharge then depends on the size and number of jets through which fuel can pass and on the fuel pressure as determined by the pressure drop in the carburetor venturi. In the "auto-lean" and "auto-rich" settings of the manual mixture control, the automatic mixture control varies the fuel pressure with changes in air density. Thus, during "auto-lean" and "auto-rich" operation, the rate of fuel discharge depends on three factors: (1) The volume of airflow through the venturi, (2) the air density, and (3) the setting of the manual mixture control.

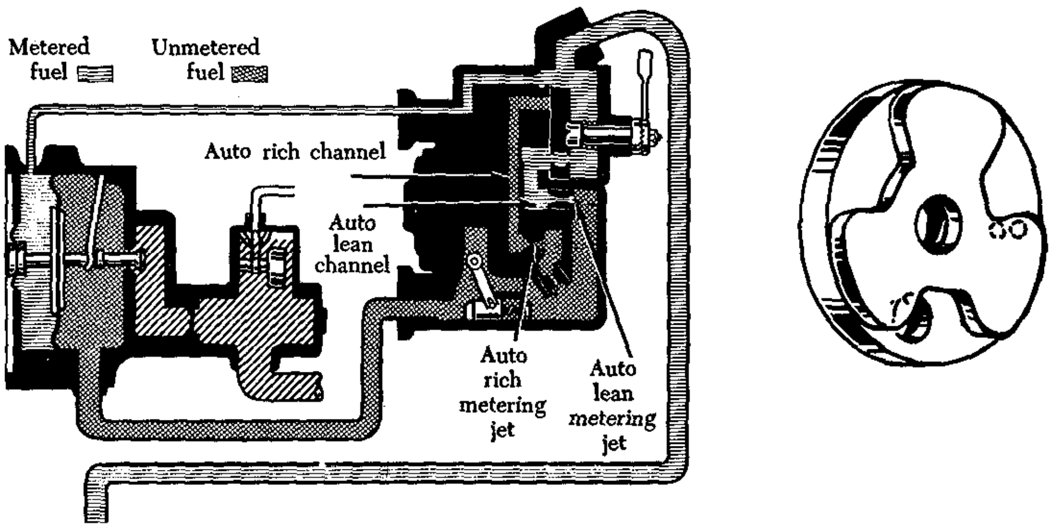


FIGURE 3–26. Manual mixture control, auto-lean setting.

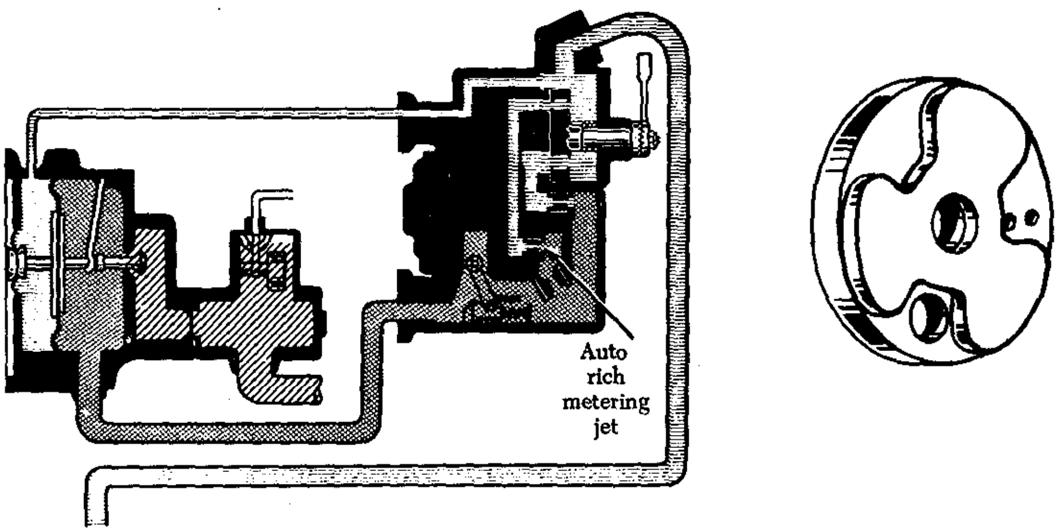


FIGURE 3–27. Manual mixture control, auto-rich setting.

Idle Cutoff System

To stop the engine, the manual mixture control lever in the cockpit is set to idle cutoff. This rotates the cloverleaf valve to the corresponding position. As shown in figure 3–28, the movable disk then covers all the openings and completely stops the fuel discharge.

Power Enrichment System

The power enrichment system is illustrated in figure 3–29. Note that the power enrichment valve is diaphragm operated. The chamber to the left of the diaphragm is connected to chamber D. A passage connects the chamber to the right of the diaphragm with the automatic lean channel. Thus, metered fuel pressure (the pressure at the discharge nozzle and in chamber C), acts on the right side of the diaphragm. At low engine speeds, the metered fuel pressure plus the force of the spring holds the valve on its seat. As the poppet valve opens farther at higher engine speeds, the pressure in chamber D increases. When this pressure, acting on the left side of the diaphragm, is high enough to overcome the combined forces of the spring and the metered fuel pressure, the power enrichment valve opens. Note how this increases the fuel flow to the discharge nozzle to provide a richer mixture for operation at high power output.

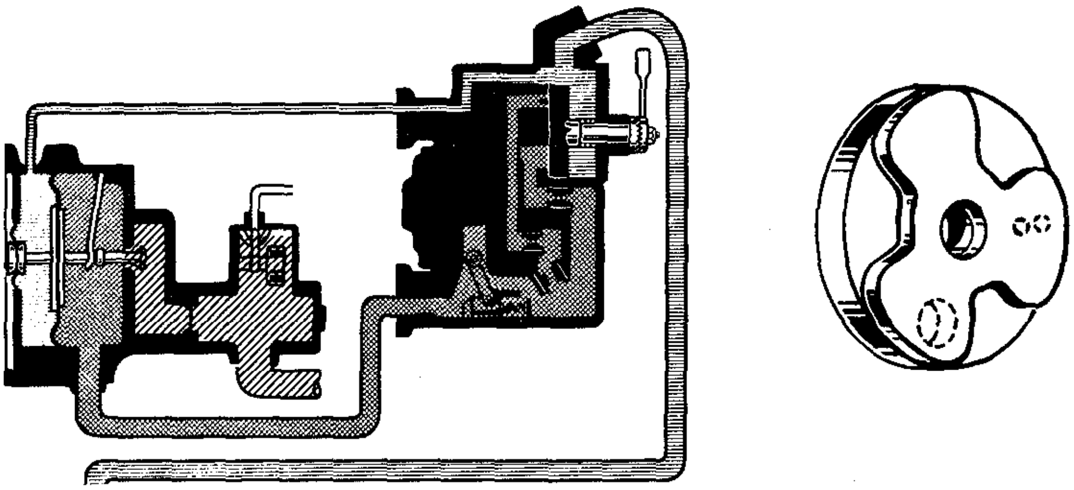


FIGURE 3–28. Manual mixture control in idle cutoff.

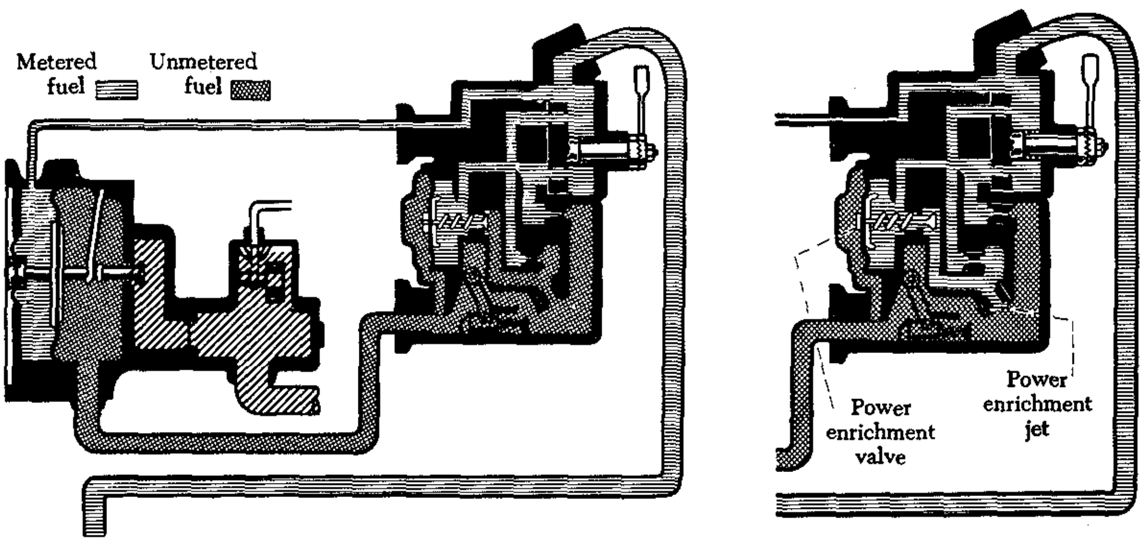


FIGURE 3–29. Power enrichment system.

STROMBERG PS SERIES CARBURETOR

The PS series carburetor is a low-pressure, single-barrel, injection-type carburetor. The carburetor consists basically of the air section, the fuel section, and the discharge nozzle, all mounted together to form a complete fuel metering system. This carburetor is similar to the pressure-injection carburetor; therefore, its operating principles are the same.

In this type carburetor (figure 3–30), metering is accomplished on a mass airflow basis. Air flowing through the main venturi creates a suction at the throat of the venturi which is transmitted to the B chamber in the main regulating part of the carburetor and to the vent side of the fuel discharge nozzle diaphragm. The incoming air pressure is transmitted to A chamber of the regulating part of the carburetor and to the main discharge bleed in the main fuel discharge jet. The discharge nozzle consists of a spring-loaded diaphragm connected to the discharge nozzle valve, which controls the flow of fuel injected into the main discharge jet. Here it is mixed with air to accomplish distribution and atomization into the airstream entering the engine.

In the PS series carburetor, as in the pressure-injection carburetor, the regulator spring has a fixed tension, which will tend to hold the poppet valve open during idling speeds, or until the D chamber pressure equals approximately 4 p.s.i. The discharge nozzle spring has a variable adjustment which, when tailored to maintain 4 p.s.i., will result in a balanced pressure condition of 4 p.s.i. in chamber C of the discharge nozzle assembly, and 4 p.s.i. in chamber D. This produces a zero drop across the main jets at zero fuel flow.

At a given airflow, if the suction created by the venturi is equivalent to one-fourth pound, this pressure decrease is transmitted to chamber B and to the vent side of the discharge nozzle. Since the area of the air diaphragm between chambers A and B is twice as great as that between chambers B and D, the one-fourth-pound decrease in pressure in chamber B will move the diaphragm assembly to the right to open the poppet valve. Meanwhile the decreased pressure on the vent side of the discharge nozzle assembly will cause a lowering of the total pressure from 4 lbs. to 3-3/4 lbs. The greater pressure of the metered fuel (4-1/4 lbs.) results in a differential across the metering head of one-fourth pound (for the one-fourth pound pressure differential created by the venturi).

The same ratio of pressure drop across the jet to venturi suction will apply throughout the range. Any increase or decrease in fuel inlet pressure will tend to upset the balance in the various chambers in the manner already described. When this occurs, the main fuel regulator diaphragm assembly repositions to restore the balance.

The mixture control, whether operated manually or automatically, compensates for enrichment at altitude by bleeding impact air pressure into B chamber, thereby increasing the pressure (decreasing the suction) in B chamber. Increasing the pressure in chamber B tends to move the diaphragm and poppet valve more toward the closed position, thus restricting fuel flow to correspond proportionately to the decrease in air density at altitude.

The idle valve and economizer jet can be combined in one assembly. The unit is controlled manually by the movement of the valve assembly. At low airflow positions, the tapered section of the valve becomes the predominant jet in the system, controlling the fuel flow for the idle range. As the valve moves to the cruise position, a straight section on the valve establishes a fixed orifice effect which controls the cruise mixture. When the valve is pulled full-open by the throttle valve, the jet is pulled completely out of the seat, and the seat size becomes the controlling jet. This jet is calibrated for takeoff power mixtures.

An airflow-controlled power enrichment valve can also be used with this carburetor. It consists of a spring-loaded, diaphragm-operated metering valve. Refer to figure 3–31 for a schematic view of an airflow power enrichment valve. One side of the diaphragm is exposed to unmetered fuel pressure, and the other side to venturi suction plus spring tension. When the pressure differential across the diaphragm establishes a force strong enough to compress the spring, the valve will open and supply an additional amount of fuel to the metered fuel circuit in addition to the fuel supplied by the main metering jet.

Accelerating Pump

The accelerating pump is a spring-loaded diaphragm assembly located in the metered fuel channel with the opposite side of the diaphragm vented to the engine side of the throttle valve. With this arrangement, opening the throttle results in a rapid decrease in suction. This decrease in suction permits the spring to extend and move the accelerating pump diaphragm. The diaphragm and spring action displace the fuel in the accelerating pump and force it out the discharge nozzle.

Vapor is eliminated from the top of the main fuel

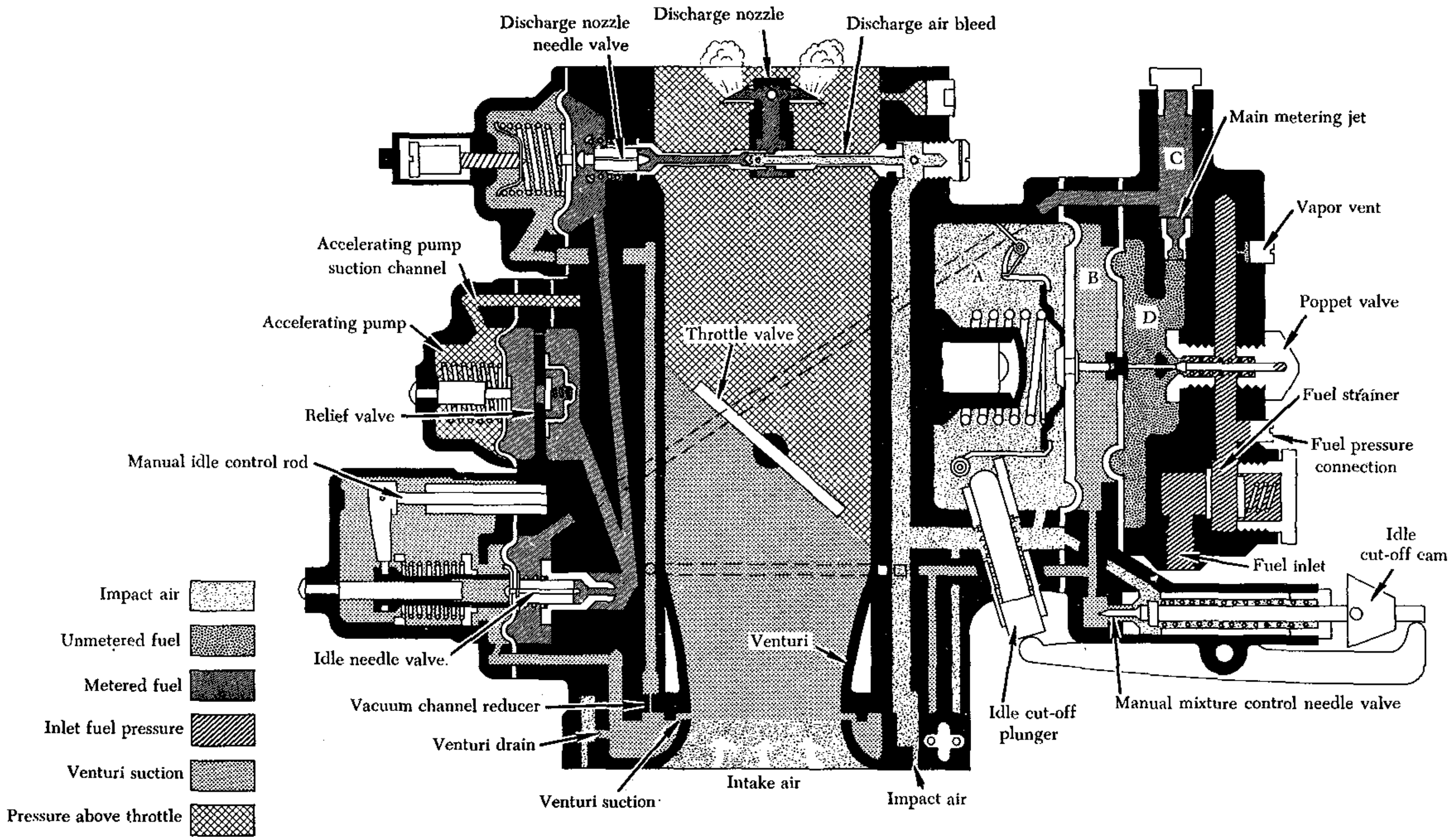


Figure 3–30. Schematic diagram of the PS series carburetor.

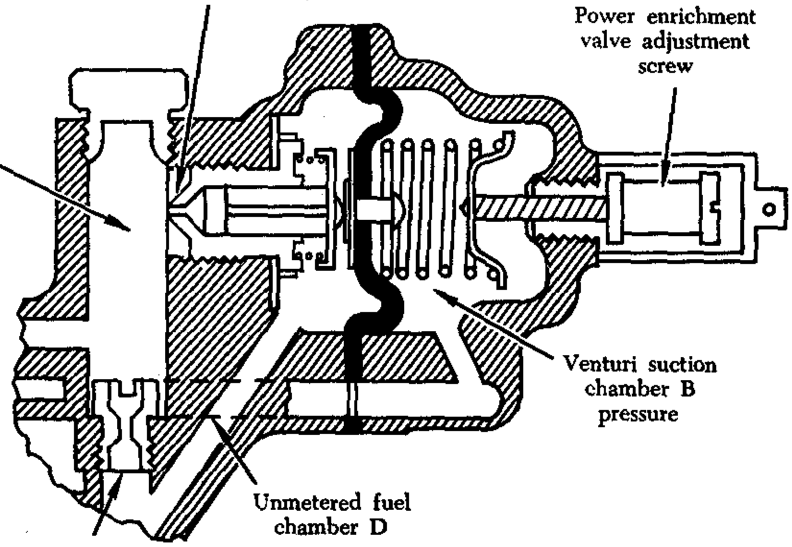


FIGURE 3–31. Airflow power enrichment valve.

chamber D through a bleed hole, then through a vent line back to the main fuel tank in the aircraft.

Manual Mixture Control

A manual mixture control provides a means of correcting for enrichment at altitude. It consists of a needle valve and seat that form an adjustable bleed between chamber A and chamber B. The valve can be adjusted to bleed off the venturi suction to maintain the correct fuel/air ratio as the aircraft gains altitude.

When the mixture control lever is moved to the "idle cutoff" position, a cam on the linkage actuates a rocker arm which moves the idle cutoff plunger inward against the release lever in chamber A. The lever compresses the regulator diaphragm spring to relieve all tension on the diaphragm between A and B chambers. This permits fuel pressure plus poppet valve spring force to close the poppet valve, stopping the fuel flow. Placing the mixture control lever in idle cutoff also positions the mixture control needle valve off its seat and allows metering suction within the carburetor to bleed off.

DIRECT FUEL-INJECTION SYSTEMS

The direct fuel-injection system has many advantages over a conventional carburetor system. There is less danger of induction system icing, since the drop in temperature due to fuel vaporization takes place in or near the cylinder. Acceleration is also improved because of the positive action of the injection system. In addition, direct fuel injection improves fuel distribution. This reduces the overheating of individual cylinders often caused by variation in mixture due to uneven distribution. The fuel-injection system also gives better fuel economy than a system in which the mixture to most cylinders must be richer than necessary so that the cylinder with the leanest mixture will operate properly.

Fuel-injection systems vary in their details of construction, arrangement, and operation. The Bendix and Continental fuel-injection systems will be discussed in this section. They are described to provide an understanding of the operating principles involved. For the specific details of any one system, consult the manufacturer's instructions for the equipment involved.

Bendix Fuel-Injection System

The Bendix RSA series fuel-injection system consists of an injector, flow divider, and fuel discharge nozzle. It is a continuous-flow system which measures engine air consumption and uses airflow forces to control fuel flow to the engine.

Fuel Injector

The fuel injector assembly consists of (1) an airflow section, (2) a regulator section, and (3) a fuel metering section. Some fuel injectors are equipped with an automatic mixture control unit.

Airflow Section

The airflow consumption of the engine is measured by sensing impact pressure and venturi throat pressure in the throttle body. These pressures are vented to the two sides of an air diaphragm. Movement of the throttle valve causes a change in engine air consumption. This results in a change in the air velocity in the venturi. When airflow through the engine increases, the pressure on the left of the diaphragm is lowered (figure 3–32) due to the drop in pressure at the venturi throat. As a result, the diaphragm moves to the left, opening the ball valve. This pressure differential is referred to as the air metering force.

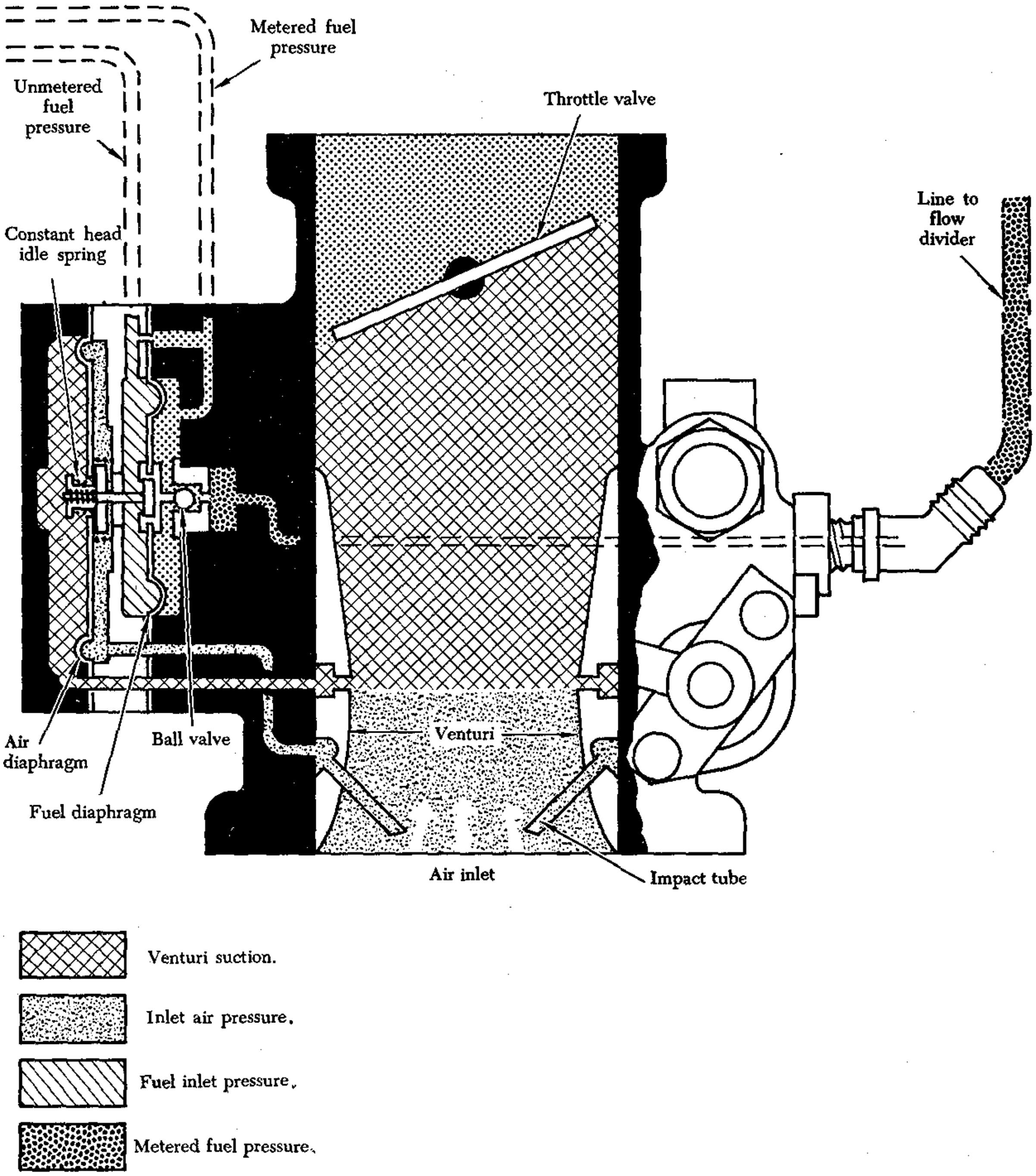


FIGURE 3–32. Airflow section of a fuel injector.

Regulator Section

The regulator section consists of a fuel diaphragm which opposes the air metering force. Fuel inlet pressure is applied to one side of the fuel diaphragm and metered fuel pressure is applied to the other side. The differential pressure across the fuel diaphragm is called the fuel metering force.

The distance the ball valve opens is determined by the difference between the pressures acting on the diaphragms. This difference in pressure is proportional to the airflow through the injector. Thus, the volume of airflow determines the rate of fuel flow.

Under low power settings the difference in pressure created by the venturi is insufficient to accomplish consistent regulation of the fuel. A constant-head idle spring is incorporated to provide a constant fuel differential pressure. This allows an adequate final flow in the idle range.

Fuel Metering Section

The fuel metering section, shown in figure 3–33, is attached to the air metering section and contains an inlet fuel strainer, a manual mixture control valve, an idle valve, and the main metering jet. In some models of injectors, a power enrichment jet is also located in this section. The purpose of the fuel metering section is to meter and control the fuel flow to the flow divider.

Flow Divider

The metered fuel is delivered from the fuel control unit to a pressurized flow divider. This unit keeps metered fuel under pressure, divides fuel to the various cylinders at all engine speeds, and shuts off the individual nozzle lines when the control is placed in idle cutoff.

Referring to the schematic diagram in figure 3–34, metered fuel pressure enters the flow divider

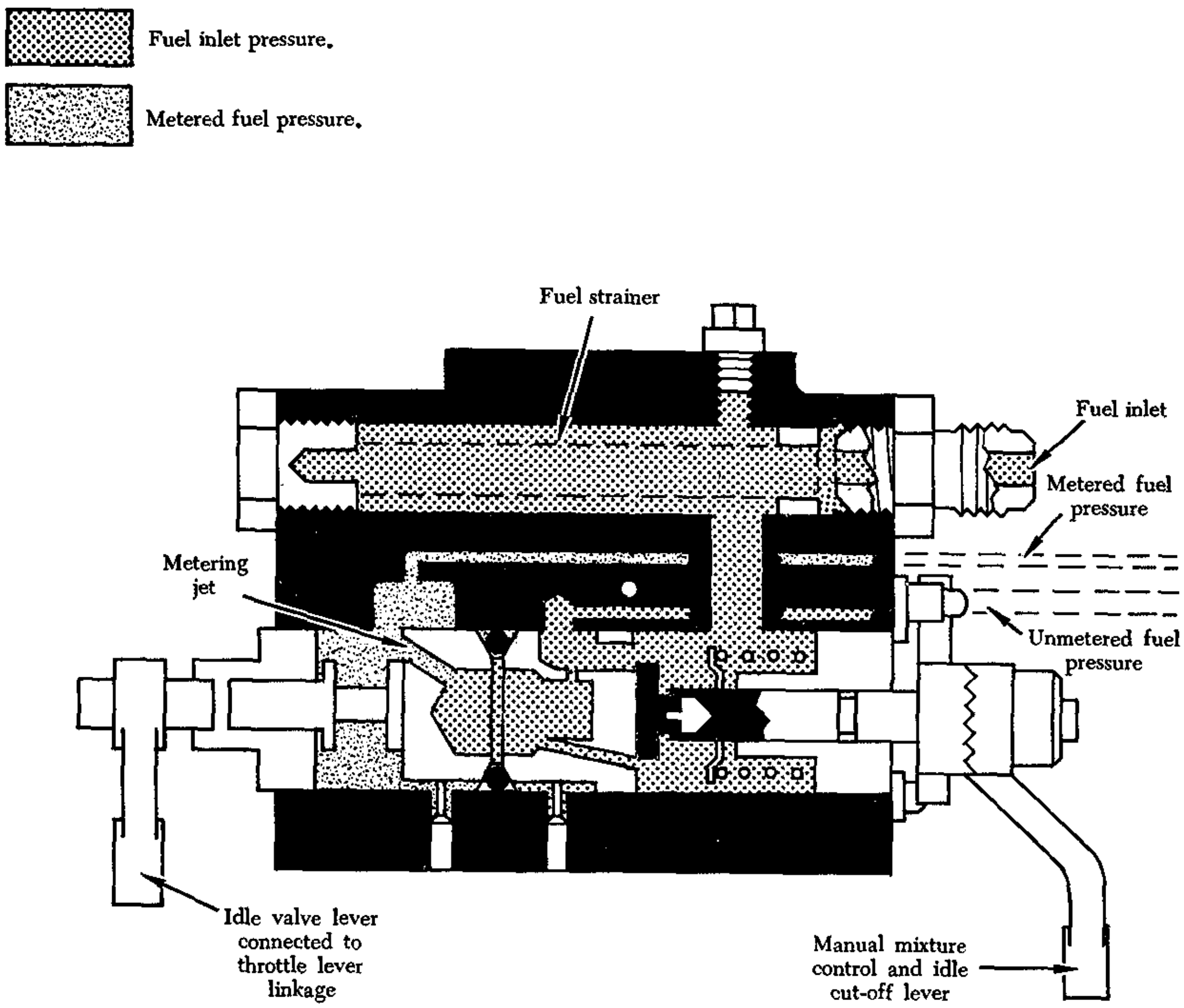


FIGURE 3–33. Fuel metering section of the injector.

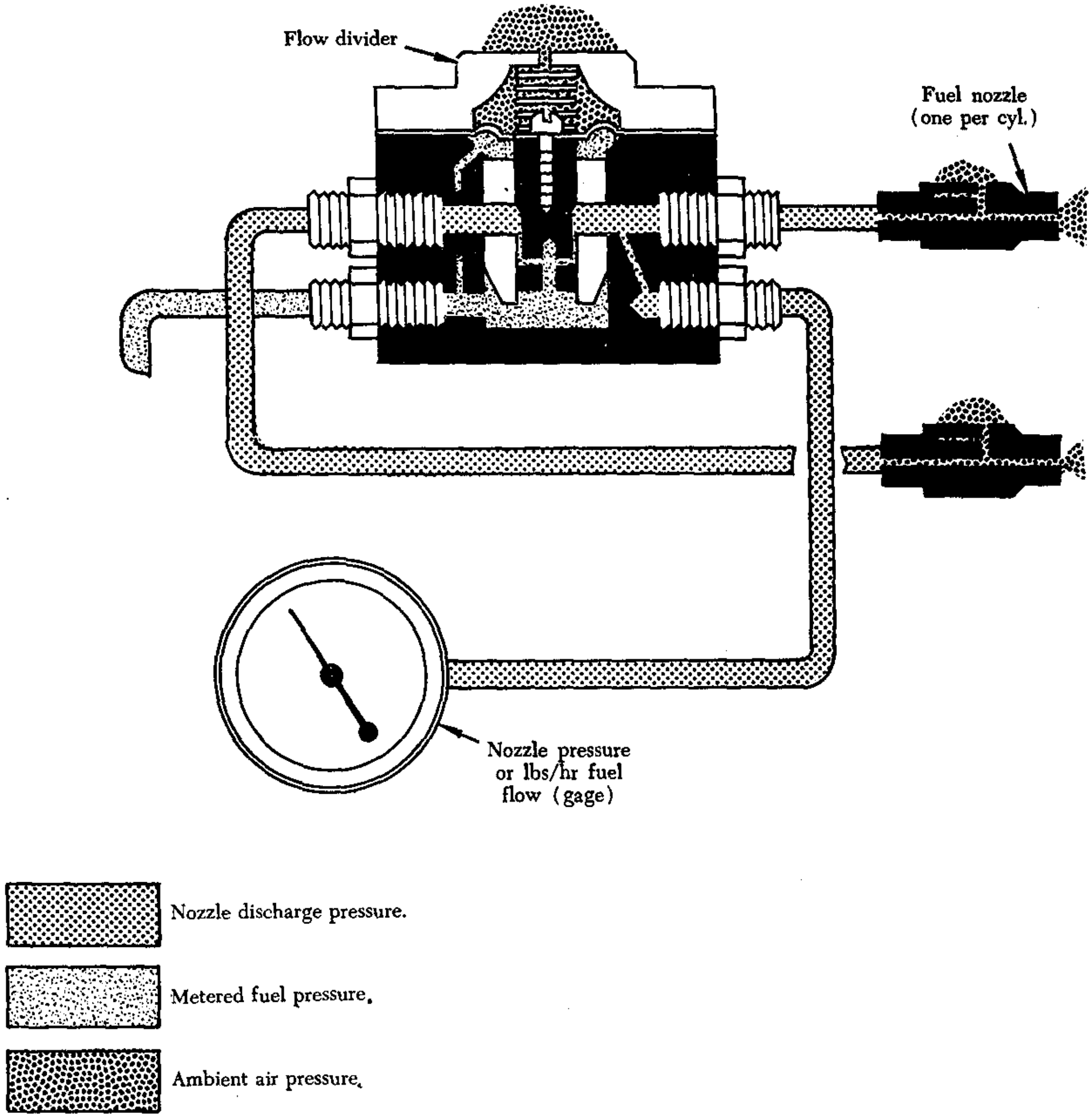


FIGURE 3–34. Flow divider.

through a channel that permits fuel to pass through the inside diameter of the flow divider needle. At idle speed, the fuel pressure from the regulator must build up to overcome the spring force applied to the diaphragm and valve assembly. This moves the valve upward until fuel can pass out through the annulus of the valve to the fuel nozzle. Since the regulator meters and delivers a fixed amount of fuel to the flow divider, the valve will open only as far as necessary to pass this amount to the nozzles. At idle the opening required is very small; thus the fuel for the individual cylinders is divided at idle by the flow divider.

As fuel flow through the regulator is increased above idle requirements, fuel pressure builds up in the nozzle lines. This pressure fully opens the flow divider valve, and fuel distribution to the engine becomes a function of the discharge nozzles.

A fuel pressure gage, calibrated in pounds-per-hour fuel flow can be used as a fuel flow meter with the Bendix RSA injection system. This gage is connected to the flow divider and senses the pressure being applied to the discharge nozzle. This pressure is in direct proportion to fuel flow and indicates the engine power output and fuel consumption.

Fuel Discharge Nozzles

The fuel discharge nozzles (figure 3–34) are of the air bleed configuration. There is one nozzle for each cylinder located in the cylinder head. The nozzle outlet is directed into the intake port. Each nozzle incorporates a calibrated jet. The jet size is determined by the available fuel inlet pressure and the maximum fuel flow required by the engine. The fuel is discharged through this jet into an ambient air pressure chamber within the nozzle assembly. Before entering the individual intake valve chambers, the fuel is mixed with air to aid in atomizing the fuel.

Continental Fuel-Injection System

The Continental fuel-injection system injects fuel into the intake valve port in each cylinder head. The system consists of a fuel injector pump, a control unit, a fuel manifold, and a fuel discharge nozzle. It is a continuous-flow type which controls fuel flow to match engine airflow. The continuous-flow system permits the use of a rotary vane pump which does not require timing to the engine.

Fuel-Injection Pump

The fuel pump is a positive-displacement, rotary-vane type, with a splined shaft for connection to the accessory drive system of the engine. A spring-loaded, diaphragm-type relief valve is provided. The relief valve diaphragm chamber is vented to atmospheric pressure. A sectional view of a fuel-injection pump is shown in figure 3–35.

Fuel enters at the swirl well of the vapor separator. Here, vapor is separated by a swirling motion so that only liquid fuel is delivered to the pump. The vapor is drawn from the top center of the swirl well by a small pressure-jet of fuel and is directed into the vapor return line. This line carries the vapor back to the fuel tank.

Ignoring the effect of altitude or ambient air conditions, the use of a positive-displacement, engine-driven pump means that changes in engine speed affect total pump flow proportionally. Since the pump provides greater capacity than is required by the engine, a recirculation path is required. By arranging a calibrated orifice and relief valve in this path, the pump delivery pressure is also maintained in proportion to engine speed. These provisions assure proper pump pressure and fuel delivery for all engine operating speeds.

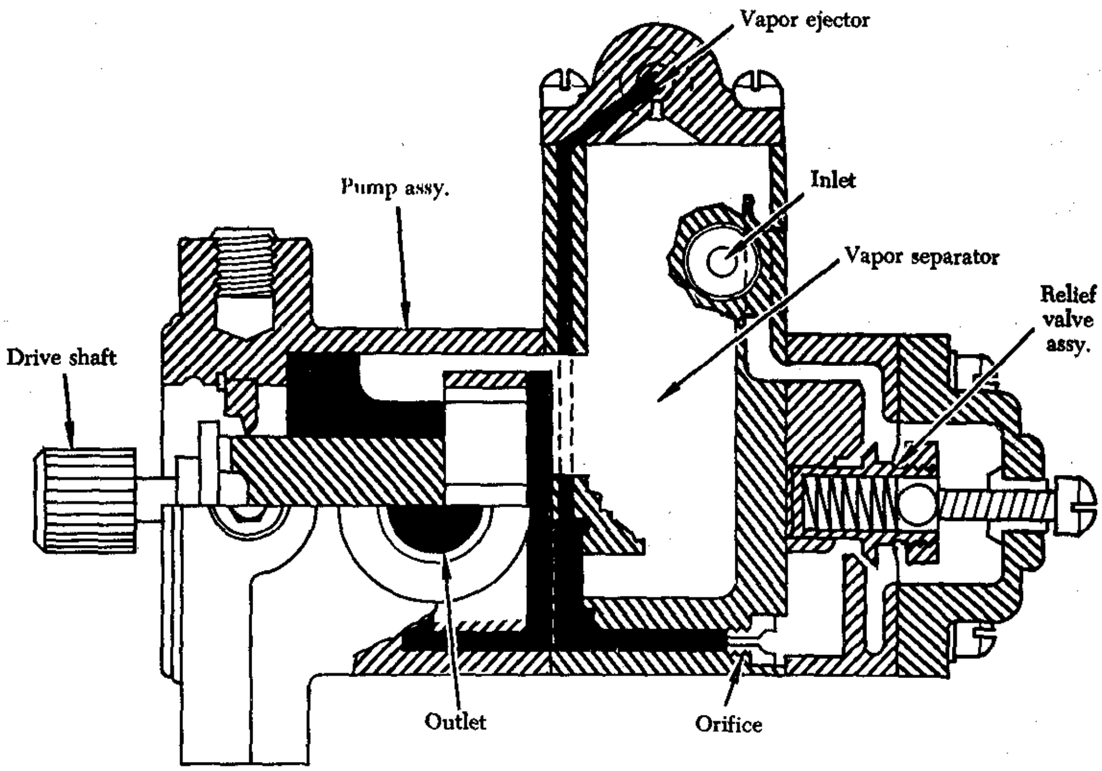


FIGURE 3–35. Fuel-injection pump.

A check valve is provided so that boost pump pressure to the system can bypass the engine-driven pump for starting. This feature also suppresses vapor formation under high ambient temperatures of the fuel. Further, this permits use of the auxiliary pump as a source of fuel pressure in the event of engine-driven pump failure.

Fuel/Air Control Unit

The function of the fuel/air control assembly is to control engine air intake and to set the metered fuel pressure for proper fuel/air ratio. The air throttle is mounted at the manifold inlet, and its butterfly valve, positioned by the throttle control in the aircraft, controls the flow of air to the engine (see figure 3–36).

The air throttle assembly is an aluminum casting

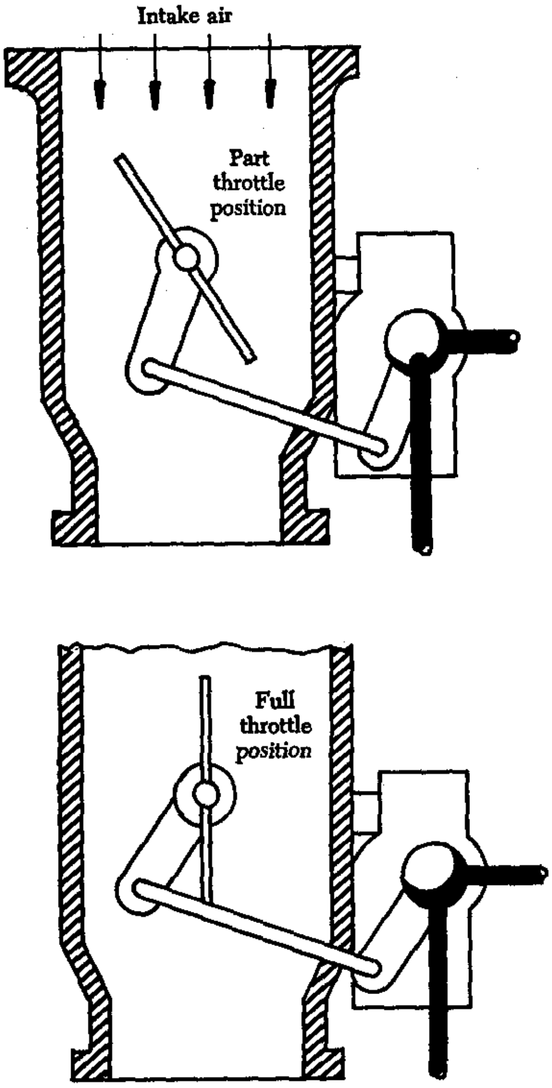


FIGURE 3–36. Fuel/air control unit.

which contains the shaft and butterfly-valve assembly. The casting bore size is tailored to the engine size, and no venturi or other restriction is used.

Fuel Control Assembly

The fuel control body is made of bronze for best bearing action with the stainless steel valves. Its central bore contains a metering valve at one end and a mixture control valve at the other end. Each stainless steel rotary valve includes a groove which forms a fuel chamber.

Fuel enters the control unit through a strainer and passes to the metering valve (figure 3–37). This rotary valve has a cam-shaped edge on the outer part of the end face. The position of the cam at the fuel delivery port controls the fuel passed to the manifold valve and the nozzles. The fuel return port connects to the return passage of the center metering plug. The alignment of the mixture control valve with this passage determines the amount of fuel returned to the fuel pump.

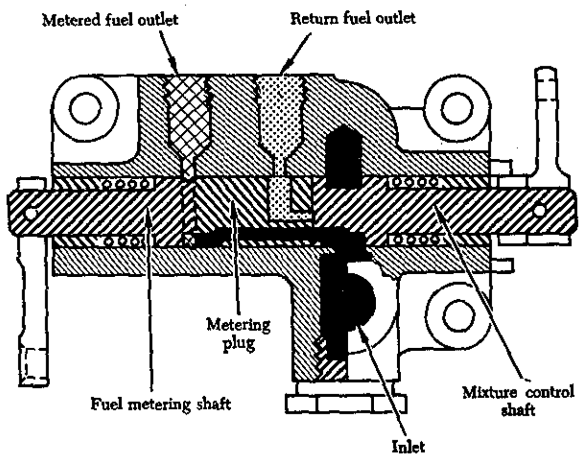


FIGURE 3–37. Fuel control assembly.

By connecting the metering valve to the air throttle, the fuel flow is properly proportioned to airflow for the correct fuel/air ratio. A control level is mounted on the mixture control valve shaft and connected to the cockpit mixture control.

Fuel Manifold Valve

The fuel manifold valve (figure 3–38) contains a fuel inlet, a diaphragm chamber, and outlet ports for the lines to the individual nozzles. The spring-loaded diaphragm operates a valve in the central bore of the body. Fuel pressure provides the force for moving the diaphragm. The diaphragm is enclosed by a cover that retains the diaphragm

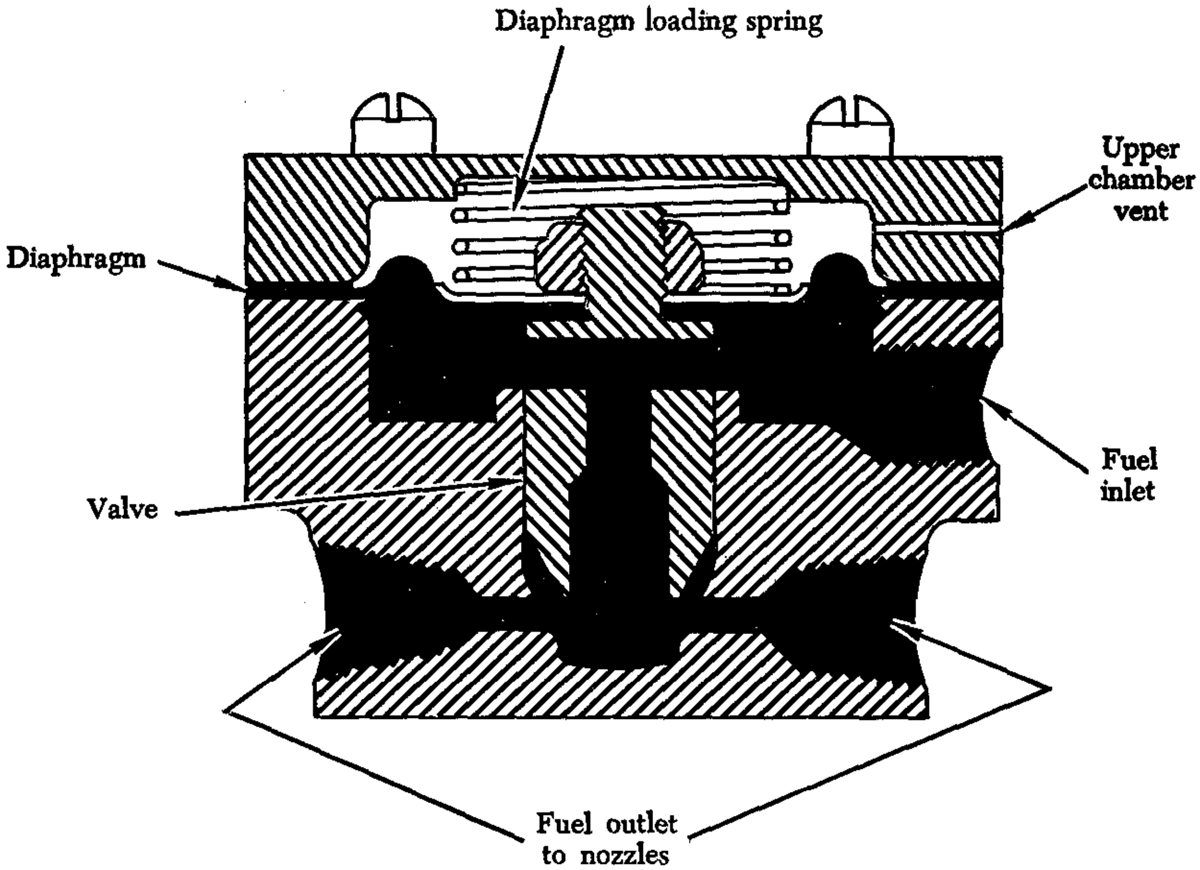


FIGURE 3–38. Fuel manifold valve assembly.

loading spring. When the valve is down against the lapped seat in the body, the fuel lines to the cylinders are closed off. The valve is drilled for passage of fuel from the diaphragm chamber to its base, and a ball valve is installed within the valve. All incoming fuel must pass through a fine screen installed in the diaphragm chamber.

From the fuel-injection control valve, fuel is delivered to the fuel manifold valve, which provides a central point for dividing fuel flow to the individual cylinders. In the fuel manifold valve a diaphragm raises or lowers a plunger valve to open or close the individual cylinder fuel supply ports simultaneously.

Fuel Discharge Nozzle

The fuel discharge nozzle is located in the cylinder head with its outlet directed into the intake port. The nozzle body, illustrated in figure 3–39, contains a drilled central passage with a counterbore at each end. The lower end is used as a chamber for fuel/air mixing before the spray leaves the nozzle. The upper bore contains a removable orifice for calibrating the nozzles. Nozzles are calibrated in several ranges, and all nozzles furnished for one engine are of the same range and are identified by a letter stamped on the hex of the nozzle body.

Drilled radial holes connect the upper counterbore with the outside of the nozzle body. These holes enter the counterbore above the orifice and draw air through a cylindrical screen fitted over the nozzle body. A shield is press-fitted on the nozzle body and extends over the greater part of the filter screen, leaving an opening near the bottom. This provides both mechanical protection and an abrupt change in the direction of airflow which keeps dirt and foreign material out of the nozzle interior.

CARBURETOR MAINTENANCE

The removal procedures will vary with both the type of carburetor concerned and the type of engine on which it is used. Always refer to the applicable manufacturer's technical instructions for a particular installation. Generally the procedures will be much the same, regardless of the type of carburetor con-

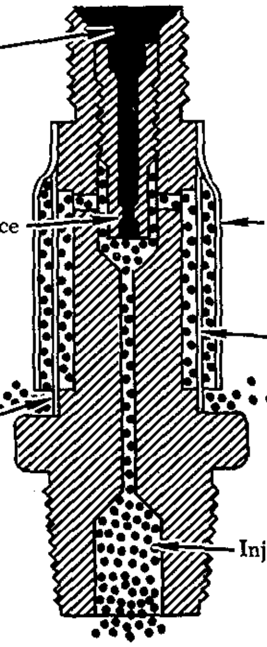


FIGURE 3–39. Fuel discharge nozzle.

cerned. Some general precautions are discussed below.

Before removing a carburetor, make sure the fuel shutoff (or selector) valve is closed. Disconnect the throttle and mixture control linkages, and lockwire the throttle valve in the closed position. Disconnect the fuel inlet line and all vapor return, gage, and primer lines. Figure 3–40 illustrates the installation connection points on a typical carburetor.

If the same carburetor is to be re-installed, do not alter the rigging of the throttle and mixture controls. Remove the airscoop or airscoop adapter. Remove the air screens and gaskets from the carburetor. Remove the nuts and washers securing the carburetor to the engine. When removing a

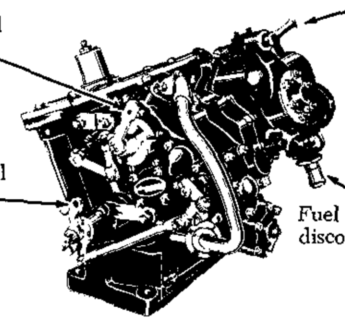


FIGURE 3–40. Carburetor installation connecting points.

downdraft carburetor, use extreme care to ensure that nothing is dropped into the engine. Remove the carburetor. Immediately install a protective cover on the carburetor mounting flange of the engine to prevent small parts or foreign material from falling into the engine. When there is danger of foreign material entering open fuel lines during removal or installation of the carburetor, plug or cover them with tape.

Installation of Carburetor

Check the carburetor for proper lockwiring before installation on an engine. Be sure that all shipping plugs have been removed from the carburetor openings.

Remove the protective cover from the carburetor mounting flange on the engine. Place the carburetor mounting flange gasket in position. On some engines, bleed passages are incorporated in the mounting pad. The gasket must be installed so that the bleed hole in the gasket is aligned with the passage in the mounting flange.

Inspect the induction passages for the presence of any foreign material before installing the carburetor.

As soon as the carburetor is placed in position on the engine, close and lockwire the throttle valves in the "closed" position until the remainder of the installation is completed.

Where it is feasible, place the carburetor deck screen in position to further eliminate the possibility of foreign objects entering the induction system.

When installing a carburetor that uses diaphragms for controlling fuel flow, connect the fuel lines and fill the carburetor with fuel. To do this, turn on the fuel booster pump and move the mixture control from the "idle cutoff" position. Continue the flow until oil-free fuel flows from the supercharger drain valve. This indicates that the preservative oil has been flushed from the carburetor.

Turn off the fuel flow, plug the fuel inlet and vapor vent outlet, and then allow the carburetor, filled with fuel, to stand for a minimum of 8 hours. This is necessary in order to soak the diaphragms and render them pliable to the degree they were when the unit was originally calibrated.

Tighten the carburetor mounting bolts to the value specified in the table of torque limits in the applicable maintenance manual. Tighten and safety any other nuts and bolts incidental to the installation of the carburetor before connecting the throttle and mixture-control levers. After the carburetor has been bolted to the engine, check the throttle and mixture-control lever on the unit for freedom of movement before connecting the control cables or linkage. Check the vapor vent lines from the carburetor to the aircraft fuel tank for restriction by blowing through the line.

Rigging Carburetor Controls

Connect and adjust carburetor or fuel metering equipment throttle controls so that full movement of the throttle is obtained with corresponding full movement of the control in the cockpit. In addition, check and adjust the throttle-control linkages so that springback on the throttle quadrant in the aircraft is equal in both the "full open" and "full closed" positions. Correct any excess play or looseness of control linkage or cables.

When installing carburetors or fuel metering equipment incorporating manual-type mixture controls that do not have marked positions, adjust the mixture control mechanism to provide an equal amount of springback at both the rich and lean end of the control quadrant in the cockpit when the mixture control on the carburetor or fuel metering equipment is moved through the full range. Where mixture controls with detents are used, rig the control mechanism so that the designated positions on the control quadrant in the aircraft will agree with the corresponding positions on the carburetor or fuel metering equipment.

In all cases check the controls for proper positioning in both the "advance" and "retard" positions. Correct excess play or looseness of control linkage or cables. Safety all controls properly to eliminate the possibility of loosening from vibration during operation.

Adjusting Idle Mixtures

Excessively rich or lean idle mixtures result in incomplete combustion within the engine cylinder, with resultant formation of carbon deposits on the spark plugs and subsequent spark plug fouling. In addition, excessively rich or lean idle mixtures make it necessary to taxi at high idle speeds with resultant fast taxi speeds and excessive brake wear. Each engine must have the carburetor idle mixture tailored for the particular engine and installation, if best operation is to be obtained.

Engines which are properly adjusted, insofar as valve operation, cylinder compression, ignition, and carburetor idle mixture are concerned, will idle at the prescribed r.p.m. for indefinite periods without loading up, overheating, or spark plug fouling. If an engine will not respond to idle mixture adjustment with the resultant stable idling characteristics previously outlined, it is an indication that some other phase of engine operation is not correct. In such cases, determine and correct the cause of the difficulty. On all aircraft installations where manifold pressure gages are used, the manifold pressure gage will give a more consistent and larger indication of power change at idle speed than will the tachometer. Therefore, utilize the manifold pressure gage when adjusting the idle fuel/air mixture. Check and adjust the idle mixture and speed on all type reciprocating engines as discussed in the following paragraphs.

Always make idle mixture adjustments with cylinder head temperatures at normal values (about 150° to 170° C.) and never with temperatures approaching the maximum allowable.

The idle mixture adjustment is made on the idle fuel control valve. It should not be confused with the adjustment of the idle speed stop. The importance of idle mixture adjustment cannot be overstressed. Optimum engine operation at low speeds can be obtained only when proper fuel/air mixtures are delivered to every cylinder of the engine. Excessively rich idle mixtures and the resultant incomplete combustion are responsible for more spark plug fouling than any other single cause. Excessively lean idle mixtures result in faulty acceleration. Furthermore, the idle mixture adjustment affects the fuel/air mixture and engine operation well up into the cruise range.

On an engine having a conventional carburetor, the idle mixture is checked by manually leaning the mixture with the cockpit mixture control. Move the carburetor mixture control slowly and smoothly toward the "idle cutoff" position. At the same time, watch the manifold pressure gage to determine whether the manifold pressure decreases prior to increasing as the engine ceases firing. The optimum mixture is obtained when a manifold pressure decrease immediately precedes the manifold pressure increase as the engine ceases firing. The amount of decrease will vary with the make and model engine and the installation. As a general rule, the amount of manifold pressure decrease will be approximately one-fourth inch.

On installations that do not use a manifold pressure gage, it will be necessary to observe the tachometer for an indication of an r.p.m. change. With most installations, the idle mixture should be adjusted to provide an r.p.m. rise prior to decreasing as the engine ceases to fire. This r.p.m. increase will vary from 10 to 50 r.p.m., depending on the installation.

Following the momentary increase in r.p.m., the engine speed will start to drop. Immediately move the mixture control back to auto-rich to prevent the engine from cutting out completely.

On direct fuel-injection engines, the mixture change during manual leaning with the mixture control is usually so rapid that it is impossible to note any momentary increase in r.p.m. or decrease in manifold pressure. Therefore, on these engines, the idle mixture is set slightly leaner than best power and is checked by enriching the mixture with the primer. To check the idle mixture on a fuel-injection installation, first set the throttle to obtain the proper idle speed. Then momentarily depress the primer switch while observing the tachometer and manifold pressure gage. If the idle mixture is correct, the fuel added by the primer will cause a momentary increase in engine speed and a momentary drop in manifold pressure. If the increase in engine speed or the decrease in manifold pressure exceeds the limits specified for the particular installation, the idle mixture is too lean (too far on the lean side of best power). If the r.p.m. drops off when the mixture is enriched with the primer, the idle mixture setting is too rich.

Before checking the idle mixture on any engine, warm up the engine until oil and cylinder head temperatures are normal. Keep the propeller control in the increase r.p.m. setting throughout the entire process of warming up the engine, checking the idle mixture, and making the idle adjustment. Keep the mixture control in auto-rich except for the manual leaning required in checking the idle mixture on carburetor-equipped engines. When using the primer to check the idle mixture on fuel-injection engines, merely flick the primer switch; otherwise, too much additional fuel will be introduced and a satisfactory indication will be obtained even though the idle mixture is set too lean.

If the check of the idle mixture reveals it to be too lean or too rich, increase or decrease the idle fuel flow as required. Then repeat the check. Continue checking and adjusting the idle mixture until it checks out properly. During this process, it may be desirable to move the idle speed stop completely out of the way and to hold the engine speed at the desired r.p.m. by means of the throttle. This will eliminate the need for frequent readjustments of the idle stop as the idle mixture is improved and the idle speed picks up. After each adjustment, "clear" the engine by briefly running it at higher r.p.m. This prevents fouling of the plugs which might otherwise be caused by incorrect idle mixture.

After adjusting the idle mixture, recheck it several times to determine definitely that the mixture is correct and remains constant on repeated changes from high power back to idle. Correct any inconsistency in engine idling before releasing the aircraft for service.

On Stromberg injection-type carburetors and direct fuel-injection master control units, the idle control link located between the idle valve stem in the fuel control unit and the idle control lever on the throttle shaft incorporates a bushing arrangement at each end (see figure 3–41). Be sure that the bolt is tight and has the washers, wave washers, and bushings assembled. In addition, there must be no play between the link and the lever. If there is any play at either end of the link, erratic mixtures will result.

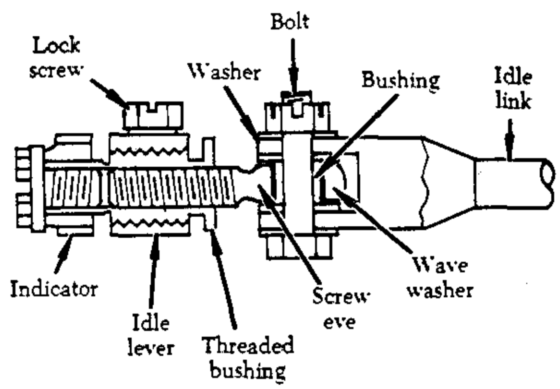


FIGURE 3–41. Idle mixture adjusting mechanism for Stromberg injection carburetors.

If sufficient mixture change cannot be accomplished by the normal idle mixture adjustment on the Stromberg injection carburetor, disconnect the link at the idle valve end by removing the bolt, washers, and wave washers. Then, to further alter the mixture, turn out or in (out to enrich, in to lean). One turn of the screw eye is equivalent to 13 notches or clicks on the normal idle adjustment.

Idle Speed Adjustment

After adjusting the idle mixture, reset the idle stop to the idle r.p.m. specified in the aircraft maintenance manual. The engine must be warmed up thoroughly and checked for ignition system malfunctioning. Throughout any carburetor adjustment procedure, run the engine up periodically to approximately half of normal rated speed to clear the engine.

Some carburetors are equipped with an eccentric screw to adjust idle r.p.m. Others use a spring-loaded screw to limit the throttle valve closing. In either case, adjust the screw as required to increase or decrease r.p.m. with the throttle retarded against the stop. Open the throttle to clear the engine; close the throttle and allow the r.p.m. to stabilize. Repeat this operation until the desired idling speed is obtained.

FUEL SYSTEM INSPECTION AND MAINTENANCE

The inspection of a fuel system installation consists basically of an examination of the system for conformity to design requirements together with functional tests to prove correct operation.

Since there are considerable variations in the fuel systems used on different aircraft, no attempt has been made to describe any particular system in detail. It is important that the manufacturer's instructions for the aircraft concerned be followed when performing inspection or maintenance functions.

Complete System

Inspect the entire system for wear, damage, or leaks. Make sure that all units are securely attached and properly safetied.

The drain plugs or valves in the fuel system should be opened to check for the presence of sediment or water. The filter and sump should also be checked for sediment, water, or slime. The filters or screens, including those provided for flowmeters and auxiliary pumps, must be clean and free from corrosion.

The controls should be checked for freedom of movement, security of locking, and freedom from damage due to chafing.

The fuel vents should be checked for correct positioning and freedom from obstruction; otherwise, fuel flow or pressure fueling may be affected. Filler neck drains should be checked for freedom from obstruction.

If booster pumps are installed, the system should be checked for leaks by operating the pumps. During this check, the ammeter or loadmeter should be read and the readings of all the pumps, where applicable, should be approximately the same.

Fuel Tanks

All applicable panels in the aircraft skin or structure should be removed and the tanks inspected for corrosion on the external surfaces, for security of attachment, and for correct adjustment of straps and slings. Check the fittings and connections for leaks or failures.

Some fuel tanks manufactured of light alloy materials are provided with inhibitor cartridges to reduce the corrosive effects of combined leaded fuel and water. Where applicable, the cartridge should be inspected and renewed at the specified periods.

Lines and Fittings

Be sure that the lines are properly supported and that the nuts and clamps are securely tightened. To tighten hose clamps to the proper torque, use a hose-clamp torque wrench. If this wrench is not available, tighten the clamp finger-tight plus the number of turns specified for the hose and clamp. (Refer to Airframe and Powerplant Mechanics General Handbook, AC 65–9, Chapter 5.) If the clamps do not seal at the specified torque, replace the clamps, the hose, or both. After installing new hose, check the clamps daily and tighten if necessary. When this daily check indicates that cold flow has ceased, inspect the clamps at less frequent intervals.

Replace the hose if the plys have separated, if there is excessive cold flow, or if the hose is hard and inflexible. Permanent impressions from the clamp and cracks in the tube or cover stock indicate excessive cold flow. Replace hose which has collapsed at the bends or as a result of misaligned fittings or lines. Some hose tends to flare at the ends beyond the clamps. This is not an unsatisfactory condition unless leakage is present.

Blisters may form on the outer synthetic rubber cover of hose. These blisters do not necessarily affect the serviceability of the hose. When a blister is discovered on a hose, remove the hose from the aircraft and puncture the blister with a pin. The blister should then collapse. If fluid (oil, fuel, or hydraulic) emerges from the pinhole in the blister, reject the hose. If only air emerges, pressure test the hose at 1-1/2 times the working pressure. If no fluid leakage occurs, the hose can be regarded as serviceable.

Puncturing the outer cover of the hose may permit the entry of corrosive elements, such as water, which could attack the wire braiding and ultimately result in failure. For this reason, puncturing the outer covering of hoses exposed to the elements should be avoided.

The external surface of hose may develop fine cracks, usually short in length, which are caused by surface aging. The hose assembly may be regarded as serviceable, provided these cracks do not penetrate to the first braid.

Selector Valves

Rotate selector valves and check for free operation, excessive backlash, and accurate pointer indication. If the backlash is excessive, check the entire operating mechanism for worn joints, loose pins, and broken drive lugs. Replace any defective parts. Inspect cable control systems for worn or frayed cables, damaged pulleys, or worn pulley bearings.

Pumps

During an inspection of booster pumps, check for the following conditions: (1) Proper operation, (2) leaks and condition of fuel and electrical connections, and (3) wear of motor brushes. Be sure the drain lines are free of traps, bends, or restrictions.

Check the engine-driven pump for leaks and security of mounting. Check the vent and drain lines for obstructions.

Main Line Strainers

Drain water and sediment from the main line strainer at each preflight inspection. Remove and clean the screen at the periods specified in the airplane maintenance manual. Examine the sediment removed from the housing. Particles of rubber are often early warnings of hose deterioration. Check for leaks and damaged gaskets.

Fuel Quantity Gages

If a sight gage is used, be sure that the glass is clear and that there are no leaks at the connections. Check the lines leading to it for leaks and security of attachment.

Check the mechanical gages for free movement of the float arm and for proper synchronization of the pointer with the position of the float.

On the electrical and electronic gages, be sure that both the indicator and the tank units are securely mounted and that their electrical connections are tight.

Fuel Pressure Gage

Check the pointer for zero tolerance and excessive oscillation. Check the cover glass for looseness and for proper range markings. Check the lines and connections for leaks. Be sure that there is no obstruction in the vent. Replace the instrument if it is defective.

Pressure Warning Signal

Inspect the entire installation for security of mounting and condition of the electrical, fuel, and air connections. Check the lamp by pressing the test switch to see that it lights. Check the operation by turning the battery switch on, building up pressure with the booster pump, and observing the pressure at which the light goes out. If necessary, adjust the contact mechanism.

WATER INJECTION SYSTEM FOR RECIPROCATING ENGINES

There are a few of these now being used, but the water injection system enables more power to be obtained from the engine at takeoff than is possible without water injection. The carburetor (operating at high-power settings) delivers more fuel to the engine than it actually needs. A leaner mixture would produce more power; however, the additional fuel is necessary to prevent overheating and detonation. With the injection of the antidetonant fluid, the mixture can be leaned out to that which produces maximum power, and the vaporization of the water-alcohol mixture then provides the cooling formerly supplied by the excess fuel, see fig. 3–42.

Operating on this best power mixture, the engine develops more power even though the manifold pressure and r.p.m. settings remain unchanged. In addition though, the manifold pressure can be increased to a point which would cause detonation without injection of the water-alcohol mixture. Thus, the increase in power with the antidetonant injection is two-fold: the engine can be operated on the best power mixture, and the maximum manifold pressure can be increased.

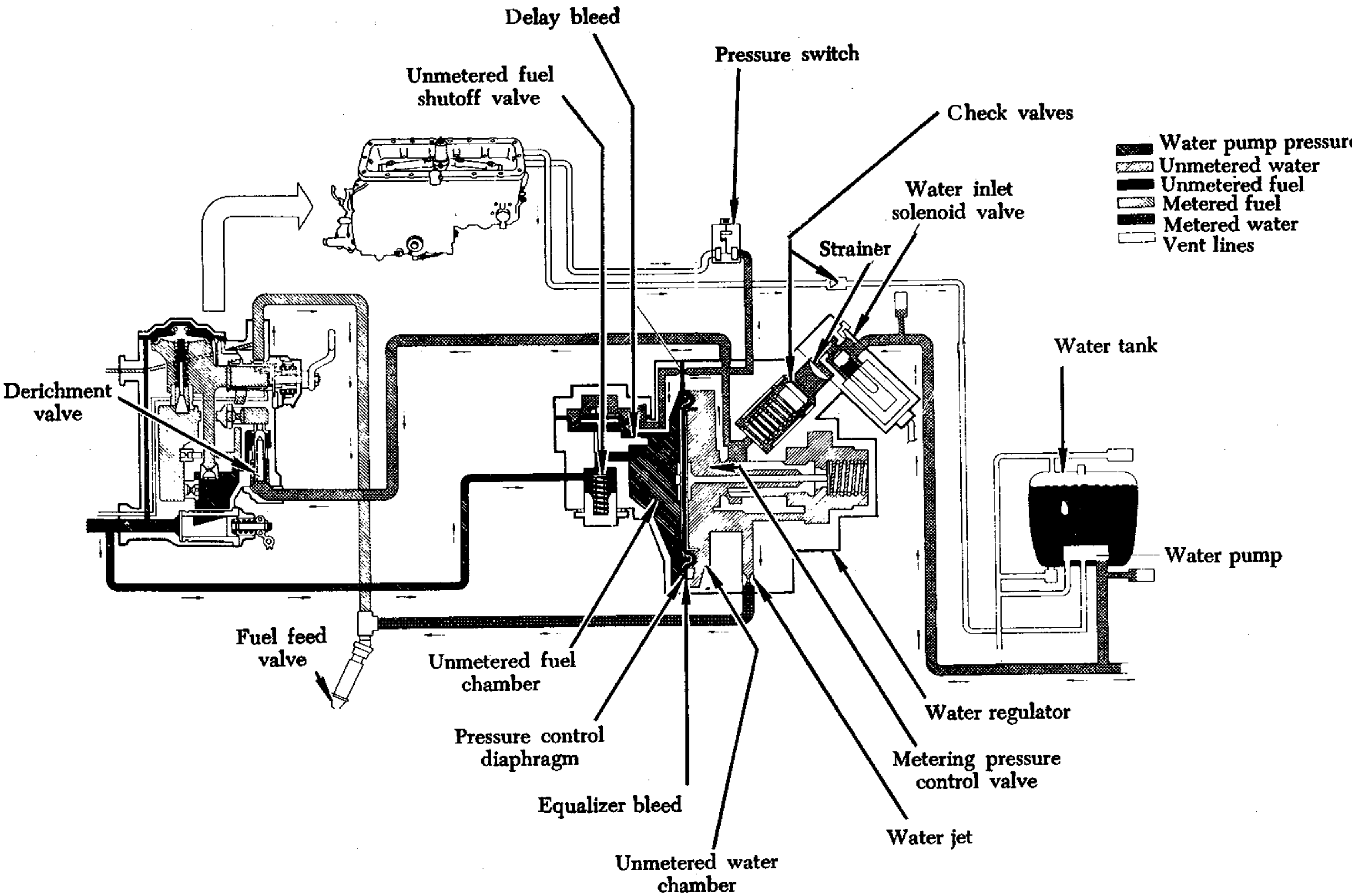


FIGURE 3–42. Schematic diagram of a typical ADI system.